# NAVAL POSTGRADUATE SCHOOL

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## MBA PROFESSIONAL REPORT

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**Analysis of an Affordability Index Model for Marine Corps Ground Combat Equipment**

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**December 2004**

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The purpose of this MBA Project is to conduct an analysis of Marine Corps Logistics Command (LOGCOM) proposed Affordability Index (AI) model. This project was conducted with the sponsorship and assistance of LOGCOM. The goal of this project is to analyze the validity and usability of the AI model, and to recommend an alternative solution. The impetus behind the AI model is to view cost-to-readiness and determine the return on investment (ROI) of allocating scarce maintenance funds on system sustainability.

The recommended alternative to the AI is a readiness-to-cost model. This alternative model produces a graphical depiction of readiness-to-cost over time. This model allows maintenance managers, commanders, and logistics analysts to conduct trend analysis on maintenance spending and readiness in order to plan and allocate maintenance funds and resources.

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**ANALYSIS OF AN AFFORDABILITY INDEX MODEL FOR MARINE CORPS GROUND COMBAT EQUIPMENT**

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Submitted in partial fulfillment of the requirements for the degree of

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# ANALYSIS OF AN AFFORDABILTY INDEX MODEL FOR MARINE CORPS GROUND COMBAT EQUIPMENT

## ABSTRACT

The purpose of this MBA Project is to conduct an analysis of Marine Corps Logistics Command (LOGCOM) proposed Affordability Index (AI) model. This project was conducted with the sponsorship and assistance of LOGCOM. The goal of this project is to analyze the validity and usability of the AI model, and to recommend an alternative solution. The impetus behind the AI model is to view cost-to-readiness and determine the return on investment (ROI) of allocating scarce maintenance funds on system sustainability.

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Not only does this report serve as the capstone to the Master of Business Administration degree, but it is also the culminating point of a lifetime of education and experience. I could not have arrived at this point without the help of so many. First and foremost, I must thank with all my heart, and all my soul, all my mind, and all my strength my Lord and Savior Jesus Christ for giving me the opportunity, patience, and wisdom to get me through what has been one of the most challenging times of my life. His blessings did not always come in the form of things one would normally associate with happiness. In fact, He tested me in many ways that, without the application of His Word, would have normally caused me severe grief had I attempted to handle them through my own human effort. However, I learned that "whenever trouble comes your way, let it be an opportunity for joy. For when your faith is tested, your endurance has a chance to grow."

During my stay in Monterey, my wife and I were blessed with a third beautiful daughter, Evangeline Grace. When she was only 8 months old, she was diagnosed with neuroblastoma. God did not forsake us. He listened to our prayers and the prayers of our friends and families. Three surgeries and 6 months of chemotherapy later, she was found to be completely cured. <u>Through His power</u>, we were able to sustain a happy household and continue, without interruption, my coursework and conquer all these challenges and bring <u>Glory to Him</u>, not to us. As the Apostle Paul said, "Since I know it is all for Christ's good, I am quite content with my weaknesses and with insults, hardships, persecutions, and calamities. For when I am weak, then I am strong."

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*-Captain John Wilkerson*

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-*Captain Joseph A. Katz*

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-*Captain Melissa C. Simmons*

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# EXECUTIVE SUMMARY

The Affordability Index (AI) model is a conceptual tool which is intended to aid logistics analysts, commanders, and maintenance planners in applying scarce maintenance funds toward systems that will best improve overall readiness for a Functional Area (FA). The AI model is intended for Marine Corps ground combat equipment TAMCNs that are reported in the Marine Corps Automated Readiness Evaluation System (MARES) per MCO 3000.11D and listed in McBul 3000.

The analysis of the AI model was conducted using eight years of historical data that was stored in the Marine Corps Integrated Maintenance Management System (MIMMS). The results of the analysis proved that the model is not a suitable tool for evaluating the "affordability" of MARES reportable items due to the upward biasing effect that the variable Unit Price (UP) has on the output.

The alternative solution to providing a useful decision support tool is the readiness-to-cost model. This model is a graphical display which allows users to conduct trend analysis of readiness and maintenance costs over time. Using the same data from the analysis of the AI model, we are able to see trends in the ratio of readiness-to-cost. It is here that we offer commanders, maintenance planners, and logistics analysts a model that can provide them with a more intuitive interpretation of the true state of systems readiness and the subsequent costs to attain and sustain that readiness.

We have recommended that this model be studied in future MBA projects to improve the model in several aspects. The current model is restricted to the use of repair parts costs, which is only one element of total support cost. We believe that future projects could focus on this particular variable of the model to determine what cost elements should be included and how to track those cost elements. The model is ideally suited for incorporation into the Marine Corps Equipment Readiness Information Tool (MERIT) system. In this regard, we believe that the model could expand into thesis topics for students in the ITM curriculum.

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# I. INTRODUCTION

> If the principles of logistics were better understood, the budgeters might be wiser and more discriminating in the manner in which they limit combat forces and at the same time the military secretaries and commanders might more effectively manage the resources allotted by the budgeters.
>
> FMFRP 12-14, Logistics in the National Defense

## A. MOTIVATION

The Marine Corps has a well-known reputation for its ability to "do more with less." While other services find their budgets shrinking, the Marine Corps has routinely been able to provide Congress with evidence to support its budget priorities[1]. But with the current operational commitments of Marines, both active duty and reserve, throughout the world in places such as Afghanistan, the Arabian Gulf, the Horn of Africa, Liberia, the Georgian Republic, Colombia, Guantanamo Bay, the Philippines, and most importantly, Operation IRAQI FREEDOM[2], ground combat equipment is being used at a rate that could not have been anticipated in prior budget submissions. In 2003, for example, over 15% of the entire Marine Corps deployed in support of Operation IRAQI FREEDOM alone.

Although the Global War on Terror continues, the current operational tempo will, at some point, subside and the Marine Corps will return to a near peacetime pace in order to reconstitute its fleet of equipment. Upon the cessation (or significant mitigation) of hostilities, the Marine Corps and other services should expect a significant reduction in funding relative to current levels. Competition for increasingly scarce maintenance resources will occur within the Marine Corps, across the services, and across other federal agencies. To meet this challenge, the Marine Corps is aggressively developing

[1] United States General Accounting Office. Defense Budget: Analysis of Operation and Maintenance Accounts for 1985-2001 (Letter Report, 02/28/97, GAO/NSIAD-97-73).

[2] Statement of General Michael W. Hagee, Commandant of the Marine Corps, before the Senate Armed Services Committee concerning posture. February 10, 2004.

decision support tools to assist materiel readiness managers in determining the most effective means of allocating scare maintenance resources across abundant alternatives under conditions of uncertainty.

## B. PURPOSE

The purpose of this research is to examine a proposed method of combining the costs associated with maintaining the Marine Corps suite of ground combat equipment with the maintenance readiness achieved by that level of funding in a way that is easily obtained, explained, and understood by materiel readiness stakeholders. We believe that such a methodology is not only timely but necessary given the increasing emphasis placed on outcomes in the Department of Defense. No longer can we merely track the expenditure of these resources, we must employ them to their greatest impact on the Marine Corps warfighting capability at the lowest cost.

## C. BACKGROUND

Until recently, little incentive existed to compare the cost of maintaining equipment to its readiness. Within the Marine Corps, the general consensus was that as long as supply and equipment readiness levels were above 90%, Commanders were satisfied. If readiness levels fell, Commanders would simply ask for more money, which invariably was forthcoming, creating the perverse incentive to maximize the use of maintenance resources to guarantee adequate funding in the future. As long as cost and readiness data were costly to obtain, lower level commanders could defend requests for increased funding due to information asymmetry. Today, advances in communications and information technology enable senior leadership to quickly compile, view, and analyze data that was once only visible at the organizational level. The days of providing anecdotal evidence to support increases in Operations & Maintenance (O&M) are rapidly disappearing.

Advances in communications and technology are not the only changes that have occurred. The emergence of terrorists of global reach, the attacks of September 11th, and Operations Enduring Freedom and Iraqi Freedom have significantly altered the national security environment. In order to cope with these changes, Secretary of Defense, Donald H. Rumsfeld directed the Department of Defense (DoD) to begin transforming the military services.

> Our agenda is clear. The global war on terror is continuing, and it will for the foreseeable future. As we prosecute the war, we'll need to continue to strengthen, improve and transform our forces; modernize and restructure programs and command, which we're working on; streamline DoD processes and procedures.
>
> **Defense Secretary Donald Rumsfeld, January 6, 2004**[3]

But what is transformation? DoD guidance describes transformation as:

> "a process that shapes the changing nature of military competition and cooperation through new combinations of concepts, capabilities, people, and organization that exploit our nation's advantages and protect against our asymmetric vulnerabilities to sustain our strategic position, which helps underpin peace and stability in the world."[4]

Transformation simply means "change." We must change the way we fight, the way we communicate, and the way we are organized. We must also change the way we conduct business. We must become more productive by first using the best business practices of industry, and secondly, by using advances in communication and technology to develop new analytical tools that are suitable for the defense services.

Transformation is nothing new to the Marine Corps. In fact, the Marine Corps is notorious for its ability to improvise, adapt, and overcome all sorts of obstacles. Although most transformation efforts tend to fail, the Marine Corps has a distinct advantage over most organizations because it has already established a culture that is conducive to transformation.

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[3] United States Department of Defense News Briefing. Transcript. http://www.defenselink.mil/transcripts/2004/tr20040106-secdef1104.html. 2004.

[4] Transformation Trends. .*Military Transformation: A Strategic Approach*. Director, Force Transformation, Office of the Secretary of Defense. Washington, D.C. Fall 2003.

Curiously, given its innovative culture, the Marine Corps currently has no uniform method for comparing the cost of maintaining its suite of ground combat equipment to the readiness achieved by that level of funding. Any cost-to-readiness analyses done in the past have been accomplished using anecdotal evidence or through non-scientific methods by highly motivated and well-meaning individuals scattered throughout the Marine Corps.

Why hasn't the Marine Corps developed tools to capture cost-to-readiness measures? It's partly due to the focus on sustaining the current suite of equipment. The primary reason, however, is that the current supply and maintenance management systems were developed in the late 1960's using computer punch-card technology. Very few database management programs were available commercially, much less within the military, to extract and compile the data from stovepiped supply and maintenance management systems. Additionally, very few Marines had the knowledge and training necessary to use the programs that were available. Establishing uniform standards across all units was thus impossible.

The situation, however, has changed. The Marine Corps now has a method of consolidating the cost-to-readiness analysis effort in one web-based system called MERIT, and then communicating it to the entire Marine Corps using current supply and maintenance management systems. Without the proper analytical tools, materiel readiness managers are struggling to provide their commanders with sound maintenance strategies given their current fiscal constraints. Improvements in the current methodology of allocating scarce maintenance resources should not only yield a greater return on investment in terms of improved readiness, but also increase the ability of the force to protect and sustain combat operations.

In order to effectively manage the resources devoted to the maintenance of combat systems, the Marine Corps must have a tool for analyzing cost and readiness trends. While the Logistics Command tracks the usage of resources as well as the readiness levels, the Marine Corps lacks information on the outcomes generated by the use of these resources. Simply put, the Marine Corps lacks the analytical methods to link expenditures to readiness outcomes.

The Marine Corps would greatly benefit by establishing a measurement for the effectiveness and affordability of ground combat equipment. With the advancements of military technology and the global mission of the Marine Corps, commanders at the Division and Marine Expeditionary Force (MEF) levels need the capability to track and influence the maintenance funding of their ground combat assets in order to maintain their combat readiness. Additionally, these commanders need a tool that may be used to justify increases in Operations and Maintenance (O&M) appropriations for the Marine Corps, as necessary, and the reallocation of appropriations, as needed, to improve readiness.

Marine Corps Logistics Command (LOGCOM) has commissioned the Graduate School of Business and Public Policy at the Naval Postgraduate School to test a theoretical model that was created as an attempt to link cost and readiness and to provide recommendations for refinement or replacement of the model if necessary. LOGCOM has provided the starting point for this research in the form of an Affordability Index (AI). Once an effective method for accomplishing the goal of associating cost and readiness has been developed, LOGCOM envisions including this methodology in the Marine Corps Equipment Readiness Information Tool (MERIT) as an additional analytical module. In this thesis, we examine the existing measures of effectiveness and affordability of ground combat systems in the United States Marine Corps, analyze the Affordability Index model, and propose a methodology to improve the allocation of resources to these combat systems.

## D. SCOPE

The readiness of the Marine Corps fleet of ground combat equipment is affected by many different factors such as the availability of funding, the number of hours the item was operated, the number of rounds fired, the quality of parts, the number and availability of mechanics and technicians, etc. Each of these factors contributes to some extent as to how well the equipment is maintained and ultimately the mean-time-between-failure rate of each item. In this thesis, however, we limit our analysis to the cost of repair parts required to perform corrective maintenance on combat-essential ground combat equipment.

The remainder of this thesis is structured as follows. In Chapter II, we describe the current methodology employed by Marine Corps leadership for the analysis and comparison of like and unlike items of equipment for the purposes of resource (budget) allocation. We also explain what the Marine Corps is currently doing to compare cost to readiness. In Chapter III, we review the literature on affordability assessments, benchmarking, and cost-to-readiness analysis methods currently employed or studied in private industry, the Department of Defense, and other government agencies. We present our data source and methodology in Chapter IV. In Chapter V, we describe and analyze the Affordability Index Model proposed by Marine Corps Logistics Command. In Chapter VI, we propose a methodology for comparing the readiness-to-cost relationship. We test the proposed model using actual historical cost and readiness data and subsequently evaluated. The last chapter concludes and offers recommendations.

# II. MATERIEL READINESS TOOLS PAST AND PRESENT

## A. INTRODUCTION

In order to fully illustrate the need for a new analytical tool and empirical methodology to explicitly link maintenance expenditures and readiness levels, we must first enumerate and describe the systems and tools currently in use within the Marine Corps. Unfortunately, there are no <u>formal</u> tools or methods currently available to all materiel readiness stakeholders for developing affordability and cost-to-readiness estimates. Each of the current systems and tools is necessary, but none is sufficient for affordability analysis and resource allocation as these tools do not link cost and readiness data. Because of the lack of uniformity, the Marine Corps' Program Objective Memorandum (POM) submissions for maintenance funding lack sufficient integration of cost and readiness data. As a result, the Marine Corps may receive inadequate funding or misallocate maintenance resources.

In this chapter, we describe the methods and models currently used by the Marine Corps to analyze the affordability and performance of ground combat weapon systems programs. We demonstrate that, while these systems are useful, they are narrowly focused, and do not provide a complete picture of what it costs to maintain the current level of maintenance readiness. We also show that organizations throughout the Marine Corps not only use widely varying methods of establishing materiel readiness strategy within their organizations, but that they also use anecdotal evidence to make affordability assessments because they lack effective cost-to-readiness and affordability assessment tools. We begin our discussion with the current supply and maintenance management systems. We then provide information concerning the analytical models currently being used in the management and allocation of resources for ground equipment.

## B. SUPPLY AND MAINTENANCE MANAGEMENT SYSTEMS

The Marine Corps captures readiness information using the Asset Tracking for Logistics and Supply System, Phase II Plus, (ATLASS II+) and the Marine Corps

Integrated Maintenance Management System (MIMMS). ATLASSII+ is currently being field tested by the II Marine Expeditionary Force (MEF), while MIMMS is being used by the rest of the Marine Corps. Supply readiness and supply parts requisition status' are reported using the Asset Tracking Logistics and Supply System and the Supported Activities Supply System. These systems are discussed below.

### 1. Marine Corps Integrated Maintenance Management System (MIMMS)

The Marine Corps manages the maintenance of its ground combat equipment using the Marine Corps Integrated Maintenance Management System (MIMMS). MIMMS operates by a set of manual procedures to control the use of personnel, money, facilities, and materiel applied to the maintenance of ground combat equipment. Its primary purpose is to increase equipment readiness with minimum expenditure by using a uniform maintenance system.[5]

MIMMS is supported by an Automated Information System (AIS) and was developed in the late 1960's using computer punch-card technology. It is capable of interfacing with existing Marine Corps systems and programs, but only to the extent that MIMMS is able to extract shipping status' for parts on order. MIMMS and MIMMS/AIS are utilized at all levels of the organization, including maintenance echelons from the individual unit up to and including the maintenance depots. It provides management visibility at the user level while simultaneously collating maintenance engineering analysis information for item management at the depot and project management levels.

MIMMS/AIS provides the equipment repair status of equipment currently in the repair cycle. The MIMMS data warehouse also contains historical maintenance management transactions. Maintenance management clerks enter into MIMMS/AIS the status of equipment currently in the repair cycle, add new equipment to the database, or correct discrepancies of previously entered data. The parts required to repair the item are entered into the Supported Activities Supply System (SASSY), which is discussed in the next section.

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[5] MCO P4790.2C w/Ch 1, "MIMMS Field Procedures Manual", Washington, D.C., July 1994.

### 2. Asset Tracking for Logistics and Supply System, Phase II Plus, (ATLASS II+)

Asset Tracking for Logistics and Supply System, Phase II Plus, (ATLASS II+) is the management information system designed to provide the U.S. Marine Corps with a real-time view of organizational and intermediate level maintenance, supply, and material readiness support. The system allows maintenance and supply officers to track all equipment, gear, and assets inducted into the maintenance cycle, to requisition parts online, and to control assets from a single, integrated platform. ATLASS II+ is the Marine Corps' integrated supply, maintenance, and material readiness system providing functional tasks and reporting features in support of asset management.

ATLASSII+ is a slight improvement over MIMMS is that it is Windows-based and much more user friendly. However, ATLASSII+ does not eliminate any of the manual procedures that are required in maintenance management technical manuals or maintenance management policy and procedures such as the requirement to continue using Equipment Repair Orders (ERO) that must be filled-out by-hand and manually input by maintenance management clerks.

### 3. Supported Activities Supply System (SASSY)

The Supported Activities Supply System (SASSY) is the mainframe computer system used to maintain accountability of inventories and requisitions within the First and Third Marine Expeditionary Force (I MEF and II MEF, respectively), Reserves, Quantico, 29Palms, and deployed forces. It is operated at the intermediate level of the supply system, at the SASSY Management Unit (SMU). SASSY performs the retail supply support functions including "stock replenishment, requirement determination, receipts, inventory, stock control, and asset visibility. It maintains requisition and accountability files for both using units and intermediate levels of inventory."[6]

Because it is operated at the intermediate level, SASSY relies on the Asset Tracking Logistics and Supply System (ATLASS) for the unit-level information and updates to the system. Information regarding the issue, receipt, or requisition of

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[6] UM 4400-124 Supported Activities Supply System

equipment is entered manually at the using unit level in ATLASS and sent daily to the SMU. Updates are batch-processed daily on the mainframe computer.

Like MIMMS, SASSY interfaces with AIS systems such as the Marine Corps Equipment Readiness Information System (MERIT), and the Joint Total Asset Visibility (JTAV), which provides users near real-time asset visibility on the battlefield. Although the ATLASS/SASSY system is antiquated and relies on manual input and processing, the information contained in the SASSY mainframe is used as input for more robust data analysis systems, such as MERIT. By combining the old with the new, the Marine Corps is making progress toward better asset tracking and logistics management.

## C. ANALYTICL MODELS/SYSTEMS

The Marine Corps has been painfully slow in developing new maintenance management systems that will more easily allow materiel readiness managers to perform effective materiel readiness analysis of ground combat equipment. ATLASSII+ has only recently been field-tested with II MEF, and as the name implies, it has gone through several iterations prior to this field-testing. Because the slow pace to develop a new information system, Marine Corps Logistics Command (LOGCOM) has taken the lead to create some tools that will use the legacy systems described above, but reformat the output to make it much more user-friendly and readable. These systems also have the added benefit of allowing materiel readiness managers to have quick access to historical data and interactive queries to use for budgeting and maintenance strategy implementation purposes. Three of these systems, MERIT, Visibility and Management of Operating and Support Costs (VAMOSC), and the System-level Total Ownership Cost (STOC), are discussed in this section. We will also explain the Depot Level Maintenance Program (DLMP). This program is essentially the closest formal process the Marine Corps has to measure the cost associated with materiel readiness.

### 1. Marine Corps Equipment Readiness Information System (MERIT)

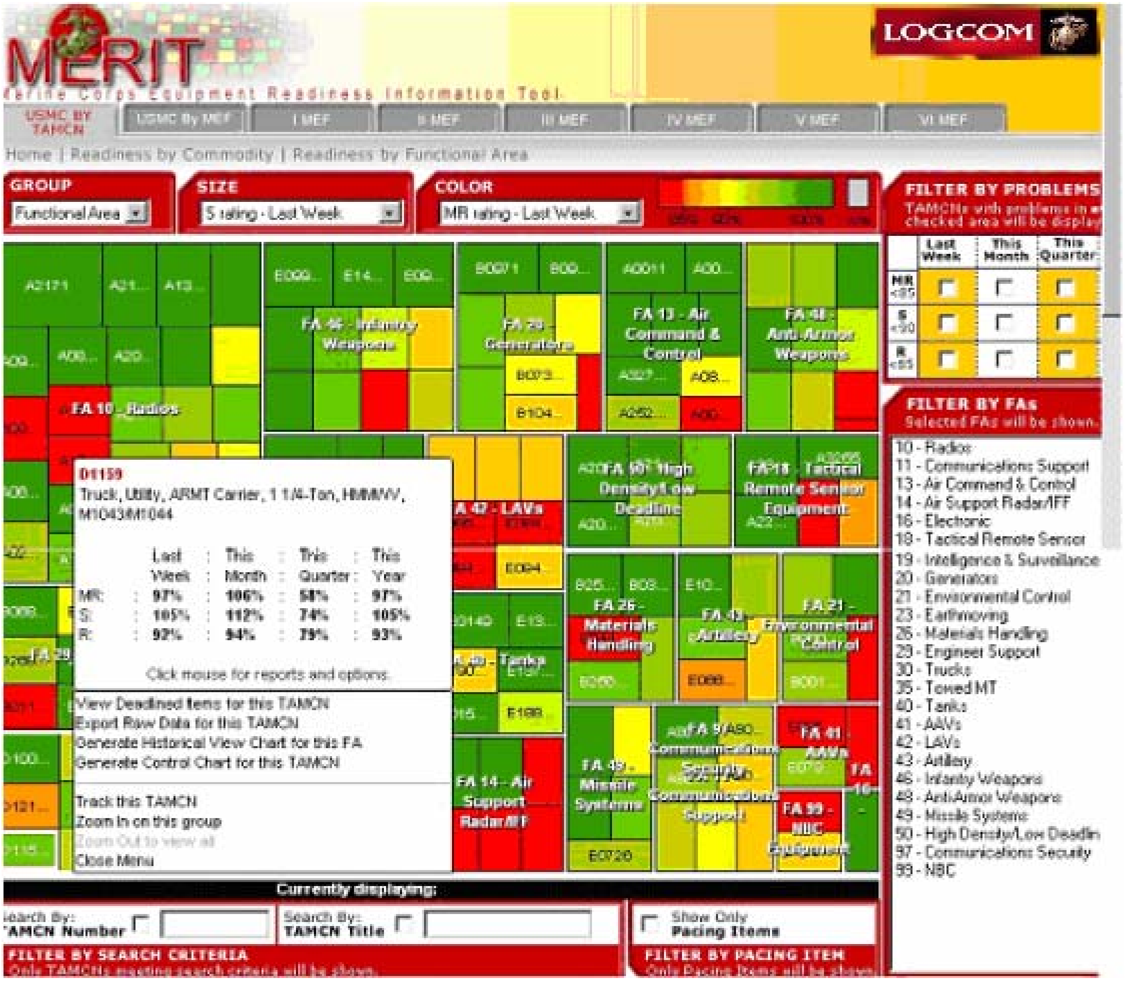
MERIT is a web-enabled tool which graphically depicts the current readiness posture and detailed supply and maintenance information for all Marine Corps readiness reportable Table of Authorized Materiel Control Numbers (TAMCN). MERIT combines

the Supply Chain Operational Performance Enabler (SCOPE) program developed in the FMF (III MEF), the Materiel Readiness Assessment Module (MRAM) program from LOGCOM (formerly known as MATCOM), the efforts of the Post Fielding Support Analysis (PFSA) initiative, and commercial-off-the-shelf (COTS) software introduced by Concurrent Technologies Corporation (CTC). MERIT extracts legacy data from Marine Corps systems such as MIMMS, ATLASSII+, and SASSY.

MERIT transforms supply and maintenance management data into valuable information that provides a dynamic adaptable view of Equipment Readiness by Commodity and Functional Area. An automatic graphics generator feature provides customized information of current and historical readiness and is ideal for developing readiness related briefing charts at all levels within the Marine Corps. Using a drilldown approach, MERIT takes the user from the top-level of Marine Corps readiness posture to the supply status of specific parts. By drastically reducing the readiness information data gathering effort, MERIT enables users to solve and prevent readiness problems.

MERIT also provides a total view of the Marine Corps readiness picture. It gives Force Commanders visibility of their readiness trends, problems and associated causes. Figure 1 is an example of one of these displays. MERIT also provides detailed information required by maintainers, Logistics Management Specialist (LMS's), Program Managers (PM's), and analysts.

Figure 1. MERIT display of Readiness by Commodity and Functional Area




Materiel readiness is an issue that affects all Marines, so as the Marine Corps moves from reactive to proactive life cycle management, it is essential that we address both current and future materiel readiness challenges. In Nov 2000, LOGCOM formed the Materiel Readiness Integrated Product Team (MRIPT), which brought together a cross-functional team that focused on materiel readiness policy, calculations, displays, reporting and procedures. First, the MRIPT identified those Materiel Readiness drivers that have the greatest impact on the Marine Corps readiness posture. Second, the MRIPT developed changes to MR policy necessary to more effectively monitor and influence MR to achieve the best-value solution from a total ownership cost perspective. Third, the MRIPT began developing an information tool, which would allow us to not only display

readiness data but would also provide a “drill down analysis” capability that could be used throughout the Marine Corps Enterprise. The bottom line is that MERIT is the tool that will move the Marine Corps toward a single materiel readiness capability.

### 2. The System-level Total Ownership Cost (STOC) Model

In an attempt to analyze cost information, the Marine Corps Logistics Command (LOGCOM) developed a cost model called the System-level Total Ownership Cost Model (STOC). The purpose of STOC was to identify various aspects of a systems life cycle cost. The STOC model identified 14 major cost elements that apply to the total cost of a system. The premise behind including the major costs associated with a system’s life cycle was to allow a program manager or analyst to view the cost of a system over its life cycle and make life cycle cost estimates based on actual data. By capturing these costs, the STOC model could be used to identify systems to invest limited resources. Table 1 below lists the 14 major cost elements that were included in the STOC model. By capturing the major operational cost elements that comprise between 60 and 80 percent of a given systems total life cycle costs, STOC served as a useful tool in providing cost elements when cost-to-readiness assessments were made. Eventually, STOC became obsolete and was replaced by Visibility and Management of Operating and Support Costs (VAMOSC).[7]

Table 1. Major Cost Elements Accumulated by the STOC Model

| | |
|---|---|
| RDT&E | Depot Maintenance |
| Procurement | Operator Training |
| Operator Labor | Maintainer Training |
| Organizational Maintenance Parts | Fuel |
| Organizational Maintenance Labor | Munitions |
| Intermediate Maintenance Parts | Post Deployment Software |
| Intermediate Maintenance Labor | Dedicated Facilities |

[7] Kuusisto, T. J., and Williamson M. A. “The Application of Data Analysis Tools To Target And Monitor Logistics-Based Improvement Programs”, United States Marine Corps Materiel Command. (n.d.).

### 3. Visibility and Management of Operating and Support Costs (VAMOSC)

The Navy Visibility and Management of Operating and Support Costs (VAMOSC) management information system collects and reports US Navy and US Marine Corps historical weapon system operating and support (O&S) costs. VAMOSC provides the direct O&S costs of weapon systems, some linked indirect costs (e.g., ship depot overhead), and related non-cost information such as flying hour metrics, steaming hours, age of aircraft, etc. Registered users may access VAMOSC data via the world-wide web. Pre-built queries are available as well as the ability to create custom queries. No special software needs to be installed on a user's desktop; only an Internet browser is required.

This relational database contains up to 20 years of data presented by fiscal year by alternative hierarchical cost element structures for 343 USMC Ground Combat Systems. The weakness with VAMOSC is that it is not able to tie the materiel readiness associated with these costs.

### 4. Depot Level Maintenance Program (DLMP)

During the 1990's, the Marine Corps Materiel Command began transforming the way in which depot maintenance funding and maintenance resources are allocated. The DLMP process was established in 1997 in order to provide "an objective and formalized depot-level maintenance requirements determination process"[8] that would accurately identify depot maintenance requirements and reduce the cost of doing business. This process is still being used by Marine Corps Materiel Readiness Officers and DoD executives and managers as a way of determining the appropriate level of Operations & Maintenance funding required for depot-level repairs.

One of the major strengths of this program is that it ensures the most beneficial allocation of maintenance funding and resources is obtained to meet the needs of the warfighter. The process achieves this goal by including a wide variety of stakeholders to include program and resource managers, but most importantly, the warfighter himself.

[8] Marine Corps Logistics Command. "*Depot Level Maintenance Program Handbook.*" Albany, Georgia. (n.d.).

The end-result of the process is a prioritized and optimized requirements list based on warfighting capabilities that balances depot maintenance requirements against life cycle management functions. Furthermore, the communication between these stakeholders has instilled confidence in the results of the process.

The major shortfall with the DLMP process is that it focuses on sustainment of current systems. The Marine Corps maintenance depots are required to ensure that the equipment in the Marine Corps inventory is operationally ready when needed. The job of determining what equipment the Marine Corps possesses is left to the Joint Chiefs, Headquarters Marine Corps, and the program managers. DLMP falls short, as the other systems above, in giving stakeholders a clear picture of how much money it takes to maintain the current or a higher level of maintenance readiness.

## D. CONCLUSION

The Marine Corps' old methods of focusing on materiel readiness and the sustainment of its ground combat equipment, although necessary, are not sufficient in today's competitive environment. The old stovepiped systems do not provide a clear picture of what it costs to maintain an appropriate readiness level. While the DLMP process is a very effective means of sustaining the fleet, we must now develop tools to capture cost-to-readiness rates.

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# III. LITERATURE REVIEW

## A. INTRODUCTION

In Chapter II, we showed that the Marine Corps currently has no formal tools or methods for measuring the affordability and cost-to-readiness of maintaining its fleet of ground combat equipment. This may seem surprising considering the huge advances in computing and data processing technology over the past 10-20 years. Clearly though, the DoD can no longer afford to continue doing business as usual. Since the DoD doesn't possess these tools, we must look to our only other source for affordability assessment models: private industry.

Although private industry is focused on maximizing shareholder wealth, while the military is focused on national defense, we can still gain valuable insights from it. We must be very careful, however, in attempting to take a cost-benefit model from the private industry and then apply it directly to the defense department. Whereas private industry has considerable flexibility in changing corporate policy to meet new threats from their competition, the federal government typically moves slowly through many bureaucratic channels, by design of course. Fortunately though, private industry is still a very valuable source of information as you will soon see.

In this chapter, we show that this thesis is an entirely new area of research, and that there are no specific tools in either industry or within the DoD that we could adopt as our model. We begin our literature review by discussing the topic of affordability as it pertains to the DoD. We then discuss other performance measurements used within private industry that are particularly useful to this thesis such as benchmarking, the SCOR model, and the merit function.

## B. AFFORDABILITY

The term "affordability" means different things to different people. In other words, it is an abstract term that is subject to interpretation. For example, the dictionary

definition of affordability is “believed to be within ones financial means.”[9] If we applied this to the Marine Corps, we would say that a particular weapon system is affordable if we have the money to acquire and sustain it. However, someone else may interpret it to mean that if weapon system A costs less than weapon system B, then weapon system A is more affordable. Even the DoD is vague when discussing affordability. In 2003, The DoD issued the following guidance in the “Defense Acquisition System,” DoD 5000.1:

> All participants in the acquisition system shall recognize the reality of fiscal constraints. They shall view cost as an independent variable, and the DoD Components shall plan programs based on realistic projections of the dollars and manpower likely to be available in future years. To the greatest extent possible, the MDAs shall identify the total costs of ownership, and at a minimum, the major drivers of total ownership costs. <u>The user shall address affordability in establishing capability needs</u>.[10]

Note that the term “affordability” is used, and in fact required, but the DoD failed to adequately define the term.

Fortunately, the Office of Naval Research (ONR) 334, Affordability Research Program has defined affordability for us as:

> the characteristic of a system that enables it to be procured when it is needed, supported so it remains available, and operated at the level of performance quality desired; all for a reasonable cost that is within the (life cycle) budget allocated to all systems being procured and operated.[11]

The definition is divided into four basic parts: acquisition, sustainability, performance, and cost. We find this definition appropriate for our study because we are focused on the last three parts. Since our study examines Marine Corps ground equipment in the operational phase of the equipment life-cycle, our model will assist materiel readiness managers in locating potential cost and readiness problems and correcting them before they become critical issues. We are using performance measures such as supply and equipment readiness percentages in our model. Obviously, the cost to support the

[9] Random House Unabridged Dictionary, 2 ed. Random House. New York. 1993.

[10] Department of Defense. “Defense Acquisition System.” DoD 5000.1, May 2003.

[11] Office of Naval Research (334). Affordability Research Program. (http://www.onr.navy.mil/sci%5Ftech/engineering/334%5Fshiphull/affordability/default.htm)

equipment at a particular readiness level is essential to this study. Therefore, we will use the ONR definition for the remainder of this report when referring to affordability issues.

## C. BENCHMARKING

One of the most important aspects of analyzing affordability and cost-to-readiness is measuring changes over time. For example, maintenance managers are interested in readiness trends to see indication of potential problems, or to see how effective a new maintenance policy has been. Another important aspect is comparing readiness performance of equipment with some established standard. This is usually referred to as benchmarking. Benchmarking is a term, initially used by manufacturing companies to compare their performance against the industry standard in which they compete, but is now used in many industries because of its usefulness as a performance measurement tool. Benchmarking is more formally defined as "a standard by which something can be measured or judged."[12]

In the book "Benchmarking Strategies: A Tool for Profit Improvement," Rob Reider defines benchmarking as:

> "A process that looks at how things are done in an organization in an effort to identify and implement internal and external best practices in a program of continuous improvement."[13]

Mr. Reider explains that benchmarking is a "comparative process." That is to say, individuals, groups, or in our case, equipment, is compared in relation to one another in order to measure how well they are performing. He lists five types of benchmarking:

1. <u>Internal Benchmarking</u>: Analysis of existing practices within various operating areas of the company identifies activities, drivers, and best performance.
2. <u>External Benchmarking</u>: External benchmarking consists of comparing company operations to other organization in some kind of formal study.
3. <u>Competitive Benchmarking</u>: Looks to the outside to identify how other direct competitors of the company are performing.

[12] Hyperdictionary. http://www.hyperdictionary.com/. 2003.

[13] Reider, Rob. "Benchmarking Strategies: A Tool for Profit Improvement." John Wiley & Sons, Inc. New York. 2000.

4. Industry Benchmarking: Attempts to identify trends, innovations, and new ideas within the company's specific industry.
5. Best-in-Class Benchmarking: Looks across multiple industries to identify new, innovative practices-regardless of their source.

Of these various types listed by Mr. Reider, only Internal Benchmarking is relevant to our study because this type of benchmark is usually associated with things such as organizational policy statements, legislation, laws, regulations, contractual and funding arrangements, budgets, schedules, and detailed plans.

This method is relevant to our study because we already have organizational policy statements concerning materiel readiness. For example, Status of Resources and Training System (SORTS) order explains that if a unit has equipment readiness greater than 90%, it is considered capable of undertaking its "full wartime missions for which it is organized or designed."[14] This measurement is also an organizational goal. So as we analyze the equipment readiness of a particular item of equipment, we could flag items that have readiness rates that fall below 90% or other break points to indicate potential problem areas.

Another example of how this method could be used is by indicating on a chart how much money was budgeted for the maintenance of an item of equipment. This line is the benchmark for budgeting purposes. If spending for the item continually exceeds this point, it may indicate that there is a performance problem with the equipment. Maintenance managers could then investigate the causes early in the process, and then implement a plan to remedy it before the problem becomes severe.

Because our study seeks to graphically illustrate changes over time for cost and maintenance readiness, and also because we believe that measuring readiness against a specific standard lends credibility to the results of cost-to-readiness models, we believe that benchmarking has merit for this thesis.

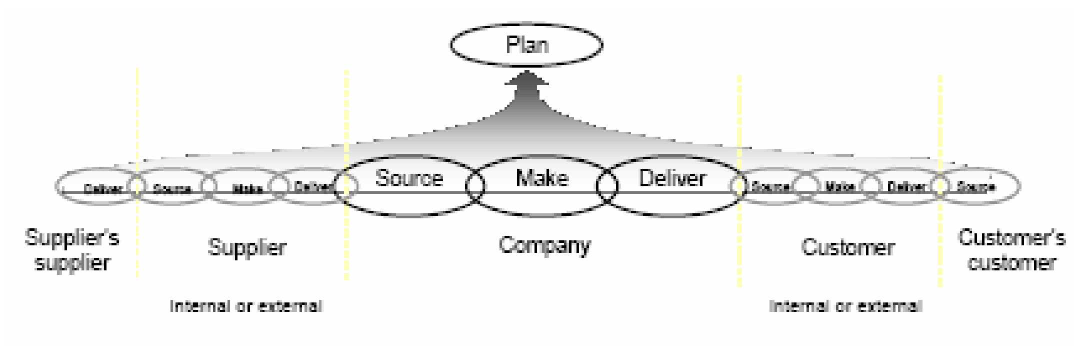
[14] Marine Corps Order P3000.13D. Status of Resources and Training System.

## D. SUPPLY CHAIN OPERATIONS REFERENCE (SCOR) MODEL

The DoD routinely seeks the expertise of governmental consulting firms to assist them in improving processes and in the development of analytical tools. One such firm is the Logistics Management Institute, a non-profit organization whose mission is simply to advance government management. In June 1999, LMI released a study called, "Supply Chain Management: A Recommended Performance Measurement Scorecard."[15] The purpose of the study was "to propose a set of balanced performance measures that senior decision-makers can use to monitor supply chain effectiveness." One of the performance measures that were discussed in the study was the SCOR model.

The SCOR model is used to examine a supply chain from the suppliers' supplier to the customer's customer. It defines the processes that make up the supply chain, assigns metrics to the processes, and then compares them to benchmarks within that particular industry. It is comprised of four management process: Plan, Source, Make, and Deliver. To understand this better, Figure 2 is shown below:

Figure 2. SCOR Model Supply Chain




The LMI study also discussed SCOR Enterprise Performance Measures that are designed to measure the efficiency and effectiveness of the DoD supply chain. The SCOR Level 1 performance measures are:

- Delivery performance

[15] Logistics Management Institute. "Supply Chain Management: A Recommended Performance Measurement Scorecard." McLean, Virginia. 1999.

- Fill rate
- Order fulfillment lead-time
- Perfect order fulfillment
- Supply chain response time
- Production flexibility
- Total supply chain management cost
- Value-added productivity
- Warranty cost
- Cash-to-cash cycle times
- Inventory days of supply
- Asset turns

Although the SCOR model includes a standard set of performance measures, some of the measures do not work very well in the DoD. For example, LMI doesn't believe warranty costs as a useful measure of the DoD supply chain because unless the maintenance depots activities offer warranties on secondary item repairs, this is not applicable. However, LMI does believe that most of these measures are very applicable to the DoD, and recommend the following measures to provide customer service, cost, and readiness and sustainability perspectives:

Customer service:

- Perfect order fulfillment
- Order fulfillment lead-time
- Supply chain response time

Cost:

- Percent change in customer price compared to inflation
- Supply chain management costs as a percentage of sales at standard price
- Inventory turns

Readiness and Sustainability Perspectives:

- Upside production flexibility

In addition to the performance measures listed above, LMI recommends that DoD include the following performance measure, which is <u>not</u> included in the SCOR model, to

the Cost Perspective: Weapon system logistics costs as a percent of acquisition price. This cost perspective is more appropriate to weapons systems than the order focus of the SCOR model. They also recommend including weapon system non-mission capable rates to the Readiness and Sustainability Perspective. Our research is applicable to these additional performance measures recommended by LMI because they directly relate to both the Affordability Index model in Chapter V and the readiness-to-cost model in Chapter VI.

In conclusion, the SCOR model is relevant to this study because successful materiel readiness strategy hinges on the supply chains ability to get the right parts and services to the right place, at the right time, and in the right quantity. Furthermore, the LMI recommendations above establish the guidance for continued study in this area of research.

## E. THE MERIT FUNCTION

Cost-benefit analysis is used when comparing different alternatives to see what economic benefits are derived from the costs associated with those alternatives. In private industry, the "benefit" most often spoken of in a cost-benefit analysis is usually focused on profit margins, however, the DoD has a difficultly in using this type of analysis because the benefits derived from the costs incurred are often <u>intangible</u>, and therefore, difficult to measure. For example, how does one measure the benefit of long-range nuclear missiles if we never use them? Is the nuclear missile actually deterring attacks against the homeland, or are our enemies simply not inclined to attack us for other reasons?

One way of approaching an analysis of this kind is by using the "merit function." The merit function has its origins in mathematics and is defined as:

> *"A function that measures the agreement between data and the fitting model for a particular choice of the parameters. By convention, the merit function is small when the agreement is good."*[16]

[16] Wolfram Research. Mathworld. http://mathworld.wolfram.com. 2004.

In 1995, a group an analysts, Edward V. Byrns, Jr., Eric Corban, and Steven A. Ingalls, conducted a study that suggested a possible method of measuring the cost-benefit of military systems using the merit function. Dr. Byrns etal defined the merit function as “the ratio of quantified system benefit to system life cycle cost” where “system benefit is measured by a unique utility function that quantifies the degree to which a given system configuration satisfies and identified set of customer requirements”, and where the life cycle cost measure “can be developed using any valid estimation technique.” The authors believe that this approach “provides for objective and reliable decision making.”[17] The authors also showed that this approach is useful for comparing similar items during the acquisition phase as well as unique items that don’t have anything from which to compare it. We believe that this approach would also be useful during the operational phase of a weapon systems life cycle because we could potentially use it to decide if we what to increase spending to achieve even higher levels of maintenance readiness.

The merit function given in the Byrns etal paper is:

$$M = B/C$$

where M represents overall merit, B derived benefit, and C Life Cycle Cost. Essentially, M is the slope of the line, so an increase in cost corresponds to an increase in benefit. A graphical example of the merit function is given in Figure 3.

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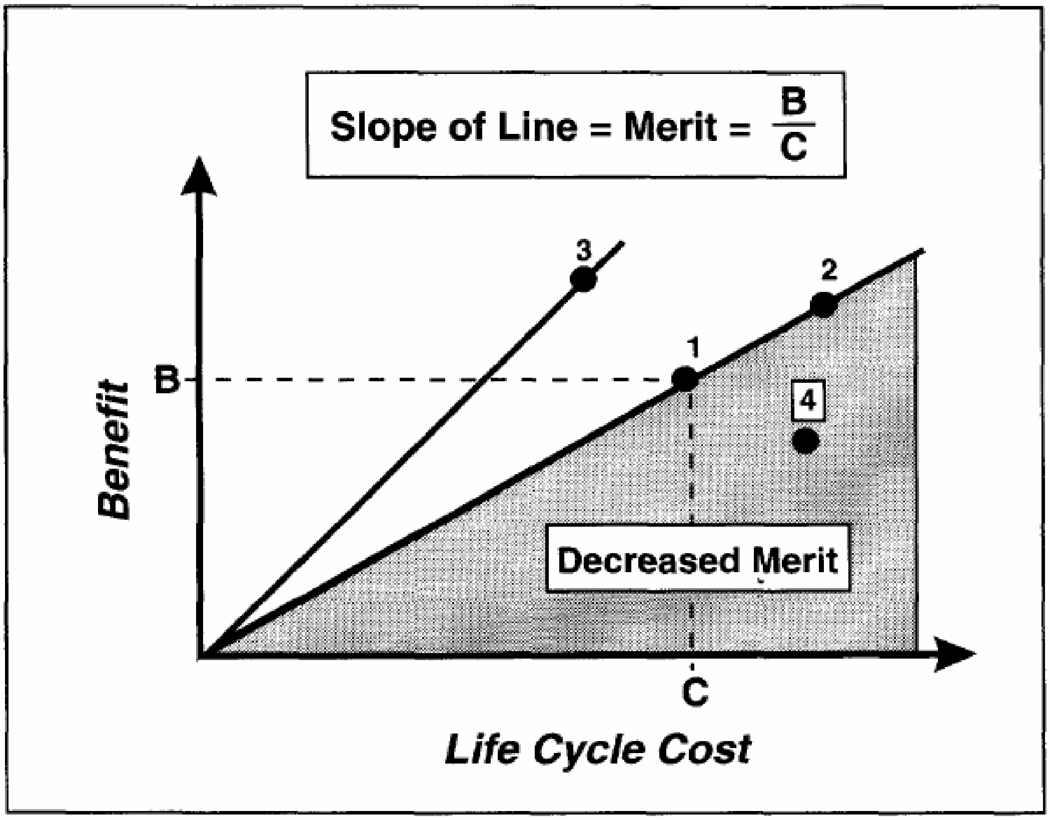
[17] Byrns, Edward V., Jr., Corban, J. Eric, and Ingalls, Stephen A. “A Novel Cost-Benefit Analysis for Evaluation of Complex Military Systems.” *Acquisition Review Quarterly*. Winter 1995.

Figure 3. Graphical Representation of the Merit Function.




In this example, there are four systems. Systems 1 and 2 have the same merit because they fall on the same line. System 4 is below the slope, therefore is has the lowest merit, and finally, System 3 has the highest merit since it falls above the slope. Therefore, a rational decision maker would chose the system with the highest merit.

Now, applying this to our study, consider a system within the Marine Corps inventory that fell on point 1. If materiel readiness managers were interested in moving the item from point 1 to point 3, they would have to develop a strategy that would simultaneously reduce cost and increase readiness. We also believe this approach would be very useful when reviewing the materiel readiness progress over time.

One of the primary issues that needs to be addressed in this method is that the analyst must ensure that the underlying circumstances that are used to calculate the level of merit, i.e. benefit and cost, are quantifiable. In our case, this is not a problem because our data comes from actual cost and readiness data obtained during the operational phase of the weapon systems.

## F. CONCLUSION

In this chapter, we provided evidence that the DoD and government consulting firms are adamant about the need for developing effective affordability assessment tools. We showed that the definition of “affordability” is vague and is subject to widely varying interpretations. We also discussed several different areas from the private industry that are useful to this study such as benchmarking, which is useful for comparing changes in performance over time, and the merit function, which provides precedence for applying a cost-to-readiness ratio when measuring the costs associated with the intangible benefits derived from those costs. Finally, we have shown that this study is unprecedented within the DoD.

# IV. DATA AND METHODOLOGY

## A. INTRODUCTION

This chapter introduces the data sources and methodology used to evaluate the Affordability Index (AI) model proposed by Marine Corps Logistics Command (LOGCOM), and for the readiness-to-cost model proposed in Chapter VI. Materiel readiness data is found exclusively in MIMMS, ATLASSII+, and SASSY. Over the past decade, many adhoc programs have been developed by nearly every organization, from the organic units to LOGCOM, because the original management-level reports have become obsolete in today's rapidly changing environment. The most recent programs, and arguably the most frequently used by materiel readiness managers, are VAMOSC and MERIT (see Chapter II), which were developed and are maintained by LOGCOM. However, the data source for these programs originates from MIMMS, ATLASSII+, and SASSY, and each will be fully described within this chapter.

## B. DATA SOURCE

The data used for this study were provided by Marine Corps Logistics Command, Albany, Georgia. We used 8 years (1996-2003) of maintenance management data entered into the Marine Corps Integrated Maintenance Management System (MIMMS) by the I and III Marine Expeditionary Force's (MEF). These two organizations were chosen because they provide a very large data sample, are active Fleet Marine Force (FMF) organizations, and have used MIMMS to enter maintenance management data for the previous eight years. II MEF, on the other hand, switched to the Asset Tracking for Logistics and Supply System, Phase II Plus, (ATLASS II+) in 2000. ATLASSII+ is simply an improved version of MIMMS that is being field-tested by II MEF.

The data consists of header and trailer information entered from the Equipment Repair Orders (ERO) of organizations throughout the Marine Corps. These organizations not only include the active duty Marine Corps, but also the Marine Corps maintenance depots, the Reserves, and other bases, posts, and stations.

## C. DATA CLEANSING

Our initial MIMMS database contained nearly 5 million Equipment Repair Orders (ERO). We wanted to capture all costs associated with the repair parts and secondary reparables located in EROs opened on Marine Corps Automated Readiness Evaluation System (MARES) reportable, combat deadlined equipment within I and III MEFs. When an ERO is opened in MIMMS, the maintenance clerk enters a maintenance category code (catcode), which identifies the criticality of the repair action being performed. The following table lists and defines each of the catcodes used in MIMMS:

Table 2. Maintenance Category Codes

| Code | Definition |
|---|---|
| M | This is a deadlined MARES reportable, i.e. mission-essential, item that requires critical maintenance which prevents the item from performing its intended mission. For example, a broken transmission on a 7-ton truck or an inoperable recoil mechanism on a 155 mm Howitzer. A general rule-of-thumb is that an item is considered deadlined if it cannot "shoot, move, or communicate." |
| X | This is a non-deadlined MARES reportable item that requires critical maintenance which degrades its ability to perform its intended mission such as an inoperable fording kit on a HMMWV (High Mobility, Multi-Wheeled, Vehicle). The HMMWV does not need its fording kit to carry troops, weapons, or equipment, but it would not be able to ford streams, thereby degrading its ability to move as designed. |
| P | A non-MARES reportable item requiring critical maintenance which deadlines or degrades the operational capability of the item. A non-MARES reportable item is any item NOT listed in the MCBul 3000 such as M-16A2 Service Rifles and the M-101 utility trailer. |
| C | This code is applicable to major components which deadline or prevent parent end items from operating at full capacity. Catcode C EROs are primarily used for intershop use. The status of the end item must be reported through the use of category code M, X, P, or N EROs. Category code C is used to distinguish between repair for return to the parent item, and return to the supply system (as in the case of secondary reparables inducted into maintenance via category code F, H, or D EROs). For example, the HMMWV is a component of a MRC-138 radio set. If the HMMWV is deadlined, two EROs would be opened - the HMMWV would be opened as a catcode M ERO, but the MRC-138 would be opened as a catcode C ERO to indicate that although the HMMWV is deadlined, the radio itself can still communicate. |
| D | Depot reparable items such as tank engine rebuilds would receive this catcode. |
| F, H | Secondary reparables such as truck alternators are identified by this catcode. |
| K | When an item only needs to be calibrated, it is identified with this code. |
| O | This code is used to capture shop overhead costs for things like pre-expended bin items that are required to maintain equipment. |
| S | SL-3 applications of operator/crew ($1^{st}$ echelon) components are identified by this code. Examples of SL-3 include things such as radio antennae's, machine gun spare barrel bags, and seat cushions and doors for vehicles. |
| N | This code is used when non-critical maintenance is needed, but only in situations where a more specific code is not applicable. |

In the initial data cleansing process, SQL was used because of the large number or records. There are many different ways one could go about cleansing the data. Regardless of how this is done, the end result must be to capture all MARES reportable EROs (or records) pertaining I and III MEF as well as the associated parts ordered on those EROs.

The most obvious place to start is by removing all units except I and III MEFs. In our study, we want to compare the cost-to-readiness of Marine Corps ground combat equipment. Because materiel readiness is measured for MARES reportable items only, we were also able to quickly remove all EROs pertaining to non-MARES reportable TAMCNs, regardless of the catcode, from the database. By default, this query also removed all catcode P EROs because this catcode is used exclusively for non-MARES reportable equipment. Just in case any catcode P EROs remained, another query was run to remove them. The remaining records to this point were EROs associated with MARES reportable TAMCNs in I and III MEFs. A simple query was run to keep only MARES reportable TAMCNs.

Again, since we are trying to compare the cost associated with maintaining the current readiness level, we decided that any catcode that did not effect readiness either positively or negatively, such as O, S, and N could be removed. As explained in Table 2, catcode O, or shop overhead, EROs are used to capture overhead costs for things like pre-expended bin items that are required to maintain equipment, and they do not deadline any equipment. As with catcode O, catcode S is not a deadlining EROs because the SL-3 gear is optional in most cases. Since catcode N is used for non-critical repairs when no other catcode is appropriate, it stands to reason that this catcode does not effect materiel readiness.

The remaining catcodes to this point were M, X, C, D, F, H, and K. We definitely wanted to keep catcode M EROs since these definitely affect MARES reportable equipment readiness, but because X EROs do not negatively effect equipment readiness rates, we removed them. Catcode K is used when calibrating equipment. While it is true that an item can be deadlined if it fails the calibration, the K ERO is closed and an appropriate deadlining ERO is opened. Consequently, we removed all K EROs based on

this understanding. Catcode D EROs are used for depot-level repairs. This catcode is used when an item it taken out of a unit's inventory and evacuated to the depot for repairs. The unit then places another item on order. The unit's supply readiness would go down accordingly, but the equipment readiness would go up since the deadlined item is no longer in the unit's inventory. When the item arrives at the depot, it loses its "identity" and goes into a maintenance pool. Once the item is repaired, it is unlikely it will be returned to the unit. It is sent back to the fleet based on the requisitioning unit possessing the highest urgency-of-need and priority. If the original unit expected to get the item back, it would use an M catcode. Therefore, all D catcodes were removed are not applicable to the FMF.

Any catcode C, or component, EROs that deadlined the major end-item was kept, and all others were eliminated. The same reasoning was used for deciding which secondary reparable catcodes, i.e. F and H, to keep.

When we completed the cleansing of the catcodes, the only catcodes remaining were M, and any C, F, or H EROs that deadlined a major end-item since these are the only types of EROs that cause equipment readiness to decrease. This is important because, as you will see in Chapter VI, we analyze a readiness-to-cost ratio that seeks to determine how much we are spending to maintain a certain level of readiness. Thus, we only need to consider deadlining catcodes.

Once we were confident we had all the relevant catcodes captured, we had to consider the parts associated with the remaining EROs. We must again make the point that because MIMMS is a very manually intensive process, it is prone to data entry errors. One of the most common places to make mistakes is while entering the 13-digit National Stock Numbers (NSN) of the required parts needed to repair an item. This is because the Equipment Repair Order Shopping List (EROSL) is handwritten by the mechanic, and then given to a supply clerk to keypunch into SASSY. Since the mechanic doesn't actually keypunch the information into SASSY, the supply clerk is occasionally unable to read the handwriting on the EROSL and subsequently enters the wrong part number. This is the primary reason there is a weekly parts reconciliation conducted between supply and maintenance. In the absence of time, we decided to remove all parts

from EROs that contained invalid NSNs. An "invalid NSN" means that either the NSN was entered incorrectly or completely missing. Incorrectly entered NSNs can come in a variety of forms, such as entering an NSN that is not associated with any part, including letters in the NSN instead of the required 13-digits, and entering something like LIMA COMPANY when the part was scrounged from another source of supply.

The data cleansing tasks mentioned here were critical in order to properly perform our analysis. Up to this point, any unit could have easily obtained this data by requesting it from LOGCOM or by using historical data dumps maintained by the unit. However, in order to analyze the Affordability Index in Chapter V and to perform cost-to-readiness analyses, we need to include all parts costs associated with the NSNs in our remaining data, obviously, as well as the replacement cost of the major end-item, and the Functional Areas (FA) (Appendix B) to which each TAMCN belongs. The parts costs and replacement costs were provided by LOGCOM are in 2003 dollars.

## D. ASSUMPTIONS

We assume that EROs in the sample data were opened and maintained in accordance with all applicable policies and directives. One of the major shortcomings of MIMMS is that it is easy to cover mistakes or to circumvent the supply system. For example, it is possible for a motor transportation mechanic to have the parts for two or more MARES reportable, combat-deadlined vehicles ordered on the same ERO in order to skew overall vehicle readiness. While the cost to repair the vehicles would not be affected, the readiness data would be based downward, which bias the cost-readiness data. While bias may be presented in the sample data, we explicitly assume that the bias in the sample is representative of that in the population.

We assume that validation of data entered into MIMMS is conducted between unit maintenance management clerks and the unit maintenance commodities on a regular basis in accordance with policy guidance to ensure that the deadline and repair statuses of all equipment are current and accurate. The procedures for entering data into MIMMS are manually intensive and require continuous management attention to ensure the data entered into the system by the maintenance management clerks is accurate. When operational tempo is high, maintenance management clerks routinely find themselves

falling behind in their data entry duties or may do their data entry in the evening after the daily MIMMS courier is sent. If an item is repaired in two days, for example, and the clerk skips his data entry one day, he may not enter the item in the system as deadlined, and therefore, it wouldn't be captured in our data. He may justify this by reasoning that items deadlined for less than 24 hours are not required to be entered into MIMMS.

We assume that the reconciliation of parts on order/cancelled is conducted between unit maintenance management clerks and the unit supply office in accordance with policy guidance. Since MIMMS and SASSY are independent systems, maintenance management policy directs maintenance management personnel to conduct weekly reconciliation of the parts on order in MIMMS to the parts actually on order in SASSY. Without proper reconciliations, we cannot be sure that the cost data is accurate.

Finally, we also assume that the total dollar value of all invalid NSNs removed during the data cleansing process discussed above were financially immaterial to the analysis.

## E. METHODOLOGY

After cleansing the data, we analyzed the AI and readiness-to-cost models. We performed the analysis of both models using Microsoft Excel. The first step in this process is partitioning the readiness and MIMMS data for two functional areas (FA). For this study, we chose FA 43-Artillery and FA 48-Anti-Armor Weapon Systems and Direct Support Equipment. These two FAs were chosen because the equipment functionality of each item within the FA is very different, although the equipment within the FA function together to perform a particular mission. For example, an M2A2 Aiming Circle is very different than a 155mm Howitzer, but they are both required for successful call-for-fire missions. This is important to note because the underlying logic behind the AI is that items within a functional area have similar cost and readiness behavior. Therefore, in order to confirm the basis of the AI model, the equipment within these FAs must have similar cost and readiness behavior.

The next step is to group the cost data obtained from MIMMS by year, and then group the readiness data by year and MEF. This enables us to calculate the total parts

costs for I and III MEFs, which is defined as Total Support Cost (TSC) in the AI model for each year. For the purposes of this study, TSC will only include total combat deadlining parts costs. Using the readiness data, we then calculate the average readiness (R), supply (S), materiel readiness (MR), quantity authorized, quantity possessed, and quantity deadlined for each MEF by year. We use the yearly average for all readiness data because we are analyzing the total parts cost data by year. Once all the readiness data is partitioned, we then sum the averages for I and III MEF by year for MR, quantity authorized, quantity possessed, and quantity deadlined, and then calculate the total average for each year. This provides us with the ability to run the data through the AI model by having all of the variables organized in a manner that is easy to view. Using the partitioned data, we then ran the AI model in order to perform our analysis. The output obtained from this step is discussed in Chapter V.

In Chapter VI, we analyze our recommendation for a readiness-to-cost model. Again, we used the same data for this model, i.e. from FAs 43 and 48 that we used for the analysis of the AI model. The readiness-to-cost model is a graphical display that views the ratio of material readiness-to-cost. The first step is to calculate the material readiness-to-cost ratio for each year. Next, we plot MR, TSC, and material readiness-to-cost. Our initial output produced displays with sharp spikes that made readability and interpretation difficult. In order to alleviate this problem, we apply data-smoothing to reduce the sharp spikes, which allow trends to surface. The data is smoothed by first calculating a two-year moving average for MR and TSC, normalizing the data by taking the moving average for each year, and then dividing it by the total eight-year average for MR, and TSC respectively.

Finally, the material readiness-to-cost ratio is calculated using the normalized values of MR and TSC. We plotted the variables and determined that the output was less dynamic, but we still noticed outliers that detracted from conducting trend analysis. Therefore, we applied the square root to MR, TSC, and material readiness-to-cost in order to bring the data points closer together, but still allow us to view trends. This is the form we used to conduct our analysis in Chapter VI.

# V. ANALYSIS OF THE AFFORDABILITY INDEX MODEL

## A. MOTIVATION

To analyze the relationship between the cost and readiness of Marine Corps ground combat equipment, the Marine Corps Logistics Command (LOGCOM) created a model called the "Affordability Index." The model seeks to provide an empirically sound methodology for examining the impact of maintenance expenditures on the readiness of ground combat equipment. In this chapter we explain and examine the Affordability Index (AI) model. We first present an overview and discuss the properties of the model, including the theory and reasoning behind its structure. Next we conduct analysis of the AI using historical cost and readiness data for two Functional Areas (FAs). We then discuss the soundness and validity of the AI model based on our findings. We conclude with insight on the application and implementation of the current model as a tool for allocation of scarce resources.

## B. OVERVIEW

The AI model is comprised of variables that are associated with current readiness reporting procedures. The model is intended for use in evaluating ground combat equipment by TAMCN. It is applicable only to the TAMCNs included in the Marine Corps Automated Readiness Evaluation System (MARES), as specified in MCO 3000.11D and contained within McBul 3000[18] because these are the only items tracked in MIMMS for readiness reporting purposes.

The impetus for the Affordability Index model was to accurately portray the cost and readiness relationship between equipment within a functional area to determine which items are performing outside the normal cost-to-readiness range within the functional area. It was based on the assumption that equipment within a functional area have similar cost and readiness rates associate with them, and therefore, would have

[18] MCO 3000.11D and MCBUL 3000, respectively, are the official publications governing the monitoring of ground equipment capability within the Marine Corps. See Appendix B for a list of all MARES reportable items.

similar AI's. If an item has a low AI relative to the other items within that FA, then that item would require increased management attention. Logically speaking, one would expect to find that changes in readiness can be attributed to the amount being spent on the maintenance and upkeep of the equipment included in the calculation of readiness.

If structured correctly, the output of the AI model would highlight which items (TAMCNs) are not providing an adequate "return on investment" and direct commanders' attention to items that may need to be replaced or managed more effectively. Those items for which readiness is declining but cost is increasing, or where cost is increasing with no resultant rise in readiness, could be deemed "unaffordable" by commanders or budgeters. The AI model is intended to analyze only one TAMCN at a time, although the output of all TAMCNs could be combined on a chart to provide a comprehensive picture of readiness. Although the AI model is structured to analyze the affordability of a TAMCN over a fiscal year, the time and/or unit size can be tailored to meet a particular analyst's needs.

The AI model and variables are listed below:

$$AI = 1 - \frac{(TSC_{\text{Active Fleet}})}{(Qty_{\text{Active}} * \text{Unit Price}_{\text{Escalated}}) / MR}$$

Total Support Cost (TSC) is the dollar amount spent to support a particular TAMCN for a specified period of time, usually a fiscal year. It does not include operating costs such as fuel, transportation, or operator labor cost. Estimates of maintenance labor and overhead costs cannot be derived from the information in MIMMS. Labor hours are supposed to be tracked in the header information for Equipment Repair Orders (ERO's) but it is not consistently tracked. It is generally missing completely or does not give an accurate account of labor hours. The limited amount of information included in the ERO header is not useful and it is therefore excluded from TSC. Although routine maintenance is a part of support costs, we included only the cost of combat deadlining parts as a proxy for Total Support Cost. "Combat deadline" refers to the status of the equipment. It means the equipment is not

ready to be used in combat. Because we are concerned with combat readiness, we exclude parts that cause a different kind of deadline—i.e. safety deadline. For example, a HMMWV with a missing mirror is not combat deadlined, but a HMMWV that needs a new alternator is combat deadlined. Parts ordered for routine maintenance do not negatively affect the readiness level of the equipment that is reported (combat readiness). Because the AI seeks to explain readiness as a function of cost, the only relevant costs are the costs of parts that have an impact on the readiness level.

Quantity (Qty) is the number of the particular TAMCN possessed by the unit or units included in the formula. Because the AI can be "scaled," the number would change depending on the size or number of units included in the AI. For example, if the I MEF Commanding General wanted to know the affordability of the ground combat equipment in I MEF, Qty would include only the total number for I MEF. On the other hand, if Congress wanted an overview of affordability for the entire Marine Corps, Qty would include the total number possessed by all Marine Corps units.

Unit Price is the original procurement price for the item, escalated to reflect current year dollars, and was obtained from LOGCOM. Unit Price is included in the model to "normalize" the data. It is based on the assumption that the ratio between TSC and Unit Price is similar for all TAMCNs and that annual support costs increase as a percentage of procurement price as the equipment ages. If this assumption were correct, the inclusion of Unit Price in the model would help to smooth the output and make the AI more sensitive. If annual support costs increase each year for all TAMCNs by a similar percentage of procurement cost, a greater rate of increase will indicate a problem. It would effectively provide a means to compare unlike FAs. If all TAMCNs and all FAs have similar relationships between TSC and UP, the model creates a basis for comparing unlike items. By including Unit Price, if the underlying assumptions are correct, the AI formula will produce an output between zero and one. However, if the assumptions are wrong, meaning that TSC does not increase each year as a percentage of UP, then the output of the AI will remain between zero and one with the results biased upward.

These underlying assumptions about Unit Price and its relationship to annual support costs do not prove true for actual data. Tables 3 and 4 provide a summary of TSC, Unit Price, and the ratio TSC:UP for FA 43 and FA 48.

Table 3. Relationship Between TSC and UP for FA 43 (1996-1998)

| FA 43 | | | | | |
|---|---|---|---|---|---|
| | **1996** | | | | |
| | **E0665** | **E1035** | **E1045** | **E1145** | **E1210** |
| **TSC** | $1,519.00 | $0.00 | $162,458.88 | $0.00 | $0.00 |
| **UP** | $1,032,337.00 | $0.00 | $218,000.00 | $0.00 | $299,115.00 |
| TSC/UP | 0.02% | 0.00% | 69.33% | 0.00% | 0.00% |
| | **1997** | | | | |
| **TSC** | $4.42 | $0.00 | $0.00 | $0.00 | $0.00 |
| **UP** | $1,032,337.00 | $0.00 | $218,000.00 | $0.00 | $299,115.00 |
| TSC/UP | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| | **1998** | | | | |
| **TSC** | $119.28 | $0.00 | $0.00 | $0.00 | $0.00 |
| **UP** | $1,032,337.00 | $520,000.00 | $218,000.00 | $0.00 | $299,115.00 |
| TSC/UP | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% |

Table 4. Relationship Between TSC and UP for FA 48 (1996-1998)

| FA 48 | | | | | |
|---|---|---|---|---|---|
| | **1996** | | | | |
| | **E0330** | **E0915** | **E0935** | **E1911** | **E1912** |
| **TSC** | $654.00 | $19.04 | $23,460.00 | $0.00 | $1,422.00 |
| **UP** | $41,051.00 | $7,833.00 | $72,000.00 | $8,994.00 | $203,199.00 |
| **TSC/UP** | 1.59% | 0.24% | 32.58% | 0.00% | 0.71% |
| | **1997** | | | | |
| **TSC** | $3,923.00 | $2.54 | $29,157.00 | $0.00 | $1.31 |
| **UP** | $41,051.00 | $7,833.00 | $72,000.00 | $8,994.00 | $203,199.00 |
| **TSC/UP** | 9.56% | 0.03% | 40.50% | 0.00% | 0.00% |
| | **1998** | | | | |
| **TSC** | $3,459.02 | $0.30 | $34,144.10 | $0.00 | $0.00 |
| **UP** | $41,051.00 | $7,833.00 | $72,000.00 | $8,994.00 | $203,199.00 |
| **TSC/UP** | 8.43% | 0.00% | 47.42% | 0.00% | 0.00% |

As you can see from Table 3 and Table 4, the ratio of TSC to UP fluctuates dramatically over a short three-year timeframe and varies greatly between TAMCNs, even within the same FA. The assumption that TSC is a similar proportion of UP for all TAMCNs is incorrect. The second assumption that TSC as a percentage of UP increases at a similar rate for all FAs is also incorrect. Due to the faulty assumptions behind the inclusion of Unit Price, it should be removed from the model.

Materiel readiness (MR) is a combination of Equipment (R) and Supply (S) readiness. The formula for deriving MR is (Qty Possessed – Qty Deadlined) / Qty Authorized. The on-hand and authorized quantities are obtained from SASSY; the deadlined quantity is from MIMMS. Like “Qty” in the numerator of the AI model, the calculation of MR should be scaled to tailor the analysis to a particular unit size.

The AI model is restricted to the active fleet for simplicity. To be accurate and thorough, TSC and quantity would include reserve units, maintenance depots, and other units such as Blount Island Command, the unit responsible for the management of equipment in the Maritime Prepositioning Program. These non-active units do not use

the same systems for tracking maintenance and supply functions as the systems used by the active fleet, making comparison of information extremely difficult. [19]

We limited our analysis to two FAs based on initial results from the model. While conducting early sensitivity analysis with FAs 43 and 48, we noted that the model displayed a high output due to the use of the variable UP. We conducted further sensitivity analysis by increasing the amount of items deadlined within a TAMCN to see if the AI would go down. From this analysis, we concluded that the AI was not responding to the amount of items in a deadlined status due to the use of UP. We then concluded that if the model could accurately portray the true state of a systems readiness posture, then it would not be a good model to reflect the “affordability” of all MARES reportable TAMCNs. We further restricted our analysis of FA 43 and 48 to IMEF and IIIMEF only. Of the three active Marine Expeditionary Forces, the First and Third use SASSY and MIMMS (as explained in Chapter II); however, the Second MEF (IIMEF) uses ATLASS II+. Because the MEFs use different systems, it is difficult to merge the data and use a single model. For our analysis we used data from IMEF and IIIMEF only.

The AI model is based on the hypothesis that systems within a functional area (FA) tend to have similar characteristics, such as mean time between failure and cost to repair. The expected result is that the AI’s of all TAMCNs within a functional area will “cluster” around a particular value. If this is true, the AI will “index” the functional area to a narrowly defined affordability range. It accounts for the fact that some functional areas may have a higher or lower AI than others, depending on the type and costs of the equipment within the FA. The index for each FA would determine the inherent affordability for the FA in general. Once the AI cluster for each FA is established, the AI would identify items within the FA that required closer examination or effort to move them back toward the baseline for their FA. Items that have a low AI, relative to their own FA, could be quickly identified by stakeholders as requiring management attention. It would allow time-constrained managers to sort through maintenance data quickly to establish effective maintenance and fiscal strategies.

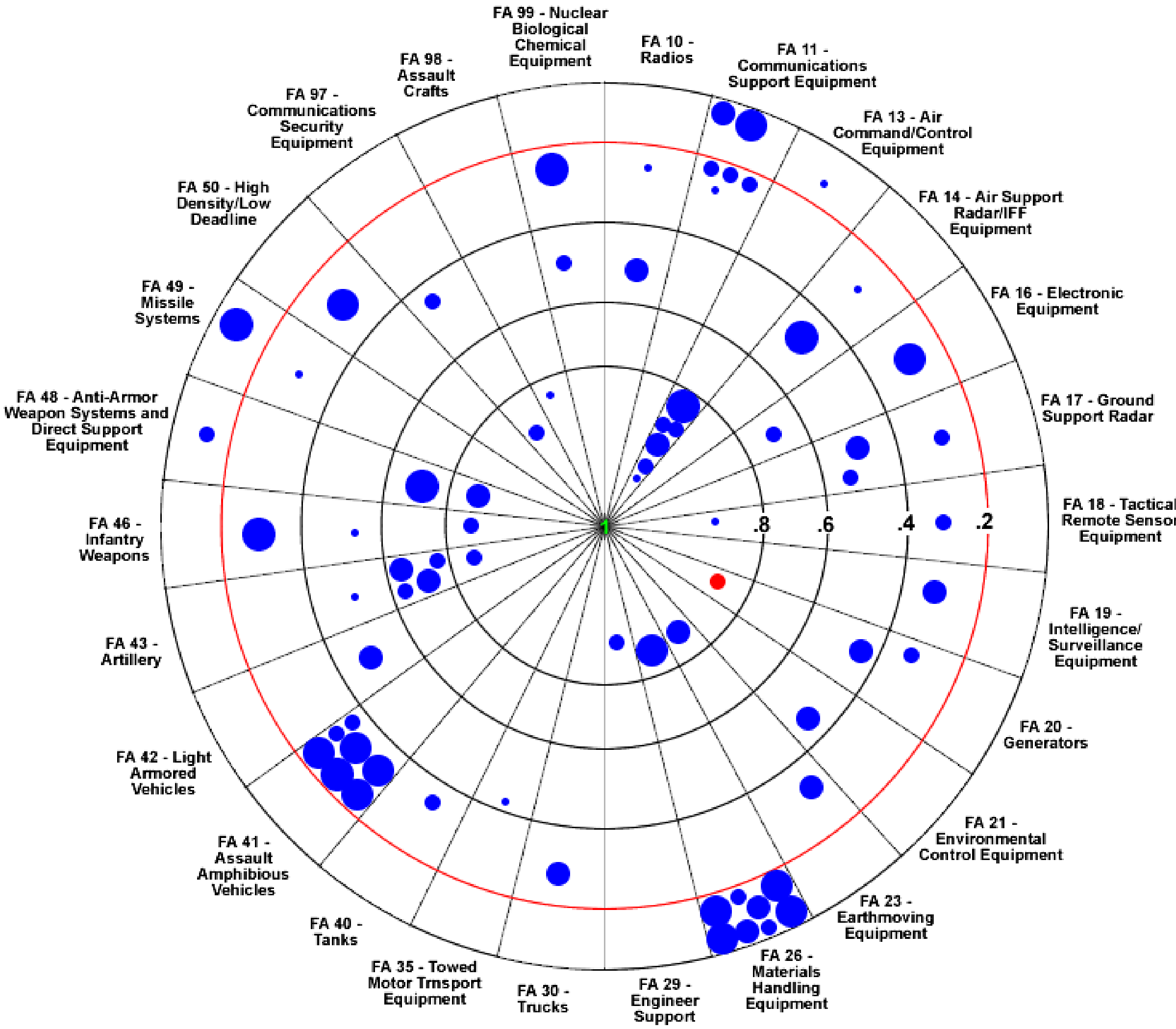
[19] This is another drawback to the current antiquated, stovepiped systems currently in use. They limit the ability to conduct thorough analysis of total costs.

By using this formula, the analyst, in theory, could view a system or unit at the division level or higher, and make informed decisions about where to apply limited resources. For example, if weapons systems within FA 43-Artillery have a baseline AI of 85% with a standard deviation of 5%, then a TAMCN with an AI of 74% in that FA would be "flagged" as requiring management attention to determine the cause of the low AI. The AI output itself does not explain the deviation but rather calls attention to the TAMCN as an outlier which requires further investigation to explain the status. Assuming the evidence shows that current readiness dollars are unable to support the desired level of readiness, the AI model would reflect a low "affordability" of maintenance for that particular TAMCN. If the model is accurate, managers could then make decisions about whether to increase spending to bring the item closer to the baseline.

This model does not provide a basis for comparison between functional areas because it is based on the assumption that each FA will have a different AI grouping. The TAMCNs within a functional area would only be compared to the other TAMCNs within the same functional area. Comparison between FAs could only be made on the basis of how closely their TAMCNs are clustered around their baseline AI or how many TAMCNs are outside an acceptable range of deviation from the baseline. The hypothesis is that a close group means all the TAMCNs are being managed effectively.

In addition to the mathematical model, LOGCOM created a notional graphical depiction of the results based on the expectations about TAMCNs within a functional area having similar characteristics. Figure 4 is based on the hypotheses and underlying assumptions about the model and does not reflect actual results. The expected result is that each FA will have a cluster but that the clusters for each FA will be different. The different sized dots are meant to display the amount of time each TAMCN has been at its current AI. The larger dots represent TAMCNs whose AI has been at the current level for a longer period of time. Smaller dots depict more recent changes.

Figure 4. Notional Output of AI Model




## C. ANALYSIS

In this section we present our analysis of the AI model for FAs 43 and 48, Artillery and Anti-Armor Weapons Systems respectively. We initially selected these two dissimilar FAs to examine the sensitivity of the model. Based on this limited initial assessment, we discovered inherent flaws with the formula. Rather than running the

model for all 24 functional areas, we used FA 43 and 48 to illustrate the fundamental problems with the model that render it invalid.

We deliberately chose dissimilar FAs to test the hypothesis that each FA will have a grouping with a different baseline. We used eight years of data records from MIMMS and SASSY for the analysis of the AI model, obtained from LOGCOM. Table 5 and Table 6 present the output of the model in Excel format for functional areas FA 43 (Artillery), and FA 48 (Anti Armor Weapons Systems and Direct Support Equipment) for fiscal years 1996-2003. Figure 5 is the actual "bullseye" chart which illustrates the results.

The output of the AI model for FA 43 and FA 48 is provided on the following pages using historical data from MIMMS and SASSY for quantity possessed, authorized, and dead-lined:

Table 5. AI Results for Functional Area 43-Artillery

**1996**

| | E0665 | E1035 | E1045 | E1145 | E1210 |
|---|---|---|---|---|---|
| TSC | $792,282.17 | $0.00 | $2,232,712.65 | $0.00 | $71,026.48 |
| Qty | 116 | 0 | 121 | 0 | 31 |
| UP | $1,032,337.00 | $0.00 | $218,000.00 | $0.00 | $299,115.00 |
| Authorized | 112 | 0 | 122 | 0 | 30 |
| Possessed | 116 | 0 | 121 | 0 | 31 |
| Deadlined | 8 | 0 | 5 | 0 | 2 |
| AI | 0.99 | 0.00 | 0.91 | 0.00 | 0.99 |

**1997**

| | E0665 | E1035 | E1045 | E1145 | E1210 |
|---|---|---|---|---|---|
| TSC | $226,729.16 | $0.00 | $1,664,413.83 | $0.00 | $347,661.02 |
| Qty | 123 | 0 | 125 | 0 | 30 |
| UP | $1,032,337.00 | $0.00 | $218,000.00 | $0.00 | $299,115.00 |
| Authorized | 117 | 0 | 127 | 0 | 29 |
| Possessed | 123 | 0 | 125 | 0 | 30 |
| Deadlined | 11 | 0 | 3 | 0 | 1 |
| AI | 1.00 | 0.00 | 0.94 | 0.00 | 0.96 |

**1998**

| | E0665 | E1035 | E1045 | E1145 | E1210 |
|---|---|---|---|---|---|
| TSC | $478,357.99 | $2,587.59 | $2,317,801.54 | $0.00 | $9,132.26 |
| Qty | 121 | 5 | 123 | 0 | 26 |
| UP | $1,032,337.00 | $520,000.00 | $218,000.00 | $0.00 | $299,115.00 |
| Authorized | 120 | 4 | 123 | 0 | 26 |
| Possessed | 121 | 5 | 123 | 0 | 26 |
| Deadlined | 14 | 1 | 7 | 0 | 2 |
| AI | 1.00 | 1.00 | 0.91 | 0.00 | 1.00 |

**1999**

| | E0665 | E1035 | E1045 | E1145 | E1210 |
|---|---|---|---|---|---|
| TSC | $427,783.66 | $6,563.12 | $1,941,652.73 | $0.00 | $168,832.10 |
| Qty | 116 | 5 | 126 | 0 | 27 |
| UP | $1,032,337.00 | $520,000.00 | $218,000.00 | $0.00 | $299,115.00 |
| Authorized | 114 | 5 | 127 | 0 | 26 |
| Possessed | 116 | 5 | 126 | 0 | 27 |
| Deadlined | 17 | 1 | 6 | 0 | 4 |
| AI | 1.00 | 1.00 | 0.93 | 0.00 | 0.98 |

**2000**

| | E0665 | E1035 | E1045 | E1145 | E1210 |
|---|---|---|---|---|---|
| **TSC** | $658,527.67 | $1,088.42 | $1,336,416.13 | $105.14 | $400,217.10 |
| **Qty** | 122 | 6 | 133 | 35 | 31 |
| **UP** | $1,032,337.00 | $520,000.00 | $218,000.00 | $25,000.00 | $299,115.00 |
| **Authorized** | 122 | 6 | 135 | 35 | 30 |
| **Possessed** | 122 | 6 | 133 | 35 | 31 |
| **Deadlined** | 16 | 1 | 6 | 1 | 4 |
| **AI** | **0.99** | **1.00** | **0.95** | **1.00** | **0.95** |

**2001**

| | E0665 | E1035 | E1045 | E1145 | E1210 |
|---|---|---|---|---|---|
| **TSC** | $99,172.55 | $4,854.46 | $1,085,260.65 | $984.45 | $69,883.67 |
| **Qty** | 125 | 6 | 136 | 41 | 31 |
| **UP** | $1,032,337.00 | $520,000.00 | $218,000.00 | $25,000.00 | $299,115.00 |
| **Authorized** | 123 | 6 | 141 | 41 | 31 |
| **Possessed** | 123 | 6 | 136 | 41 | 31 |
| **Deadlined** | 13 | 1 | 9 | 1 | 6 |
| **AI** | **1.00** | **1.00** | **0.96** | **1.00** | **0.99** |

**2002**

| | E0665 | E1035 | E1045 | E1145 | E1210 |
|---|---|---|---|---|---|
| **TSC** | $310,696.02 | $3,997.19 | $1,736,646.04 | $1,652.24 | $227,449.77 |
| **Qty** | 121 | 8 | 134 | 43 | 33 |
| **UP** | $1,032,337.00 | $520,000.00 | $218,000.00 | $25,000.00 | $299,115.00 |
| **Authorized** | 120 | 8 | 135 | 43 | 33 |
| **Possessed** | 121 | 8 | 134 | 43 | 33 |
| **Deadlined** | 19 | 1 | 5 | 2 | 5 |
| **AI** | **1.00** | **1.00** | **0.94** | **1.00** | **0.97** |

**2003**

| | E0665 | E1035 | E1045 | E1145 | E1210 |
|---|---|---|---|---|---|
| **TSC** | $593,663.13 | $1,746.82 | $1,121,372.48 | $9,861.00 | $307,667.36 |
| **Qty** | 131 | 5 | 124 | 42 | 30 |
| **UP** | $1,032,337.00 | $520,000.00 | $218,000.00 | $25,000.00 | $299,115.00 |
| **Authorized** | 129 | 6 | 130 | 42 | 31 |
| **Possessed** | 131 | 5 | 124 | 42 | 30 |
| **Deadlined** | 27 | 0 | 6 | 2 | 4 |
| **AI** | **0.99** | **1.00** | **0.95** | **0.99** | **0.96** |

Table 6. AI Results for Functional Area 48-Anti Armor Weapons Systems

**1996**

| | E0330 | E0915 | E0935 | E1911 | E1912 |
|---|---|---|---|---|---|
| **TSC** | $161,665.07 | $69,747.13 | $1,296,186.16 | $529.00 | $251,000.66 |
| **Qty** | 277 | 421 | 290 | 37 | 45 |
| **UP** | $41,051.00 | $7,833.00 | $72,000.00 | $8,994.00 | $203,199.00 |
| **Authorized** | 284 | 371 | 289 | 49 | 41 |
| **Possessed** | 277 | 421 | 290 | 37 | 45 |
| **Deadlined** | 14.00 | 16.00 | 11.00 | 0.00 | 2.00 |
| **AI** | **0.98** | **0.98** | **0.94** | **1.00** | **0.97** |

**1997**

| | E0330 | E0915 | E0935 | E1911 | E1912 |
|---|---|---|---|---|---|
| **TSC** | $138,048.93 | $58,281.73 | $691,577.59 | $711.19 | $999,015.88 |
| **Qty** | 279 | 412 | 283 | 48 | 46 |
| **UP** | $41,051.00 | $7,833.00 | $72,000.00 | $8,994.00 | $203,199.00 |
| **Authorized** | 285 | 397 | 282 | 52 | 45 |
| **Possessed** | 279 | 412 | 283 | 48 | 46 |
| **Deadlined** | 11.00 | 14.00 | 12.00 | 1.00 | 5.00 |
| **AI** | **0.99** | **0.98** | **0.96** | **1.00** | **0.88** |

**1998**

| | E0330 | E0915 | E0935 | E1911 | E1912 |
|---|---|---|---|---|---|
| **TSC** | $65,413.83 | $37,570.03 | $997,679.14 | $746.00 | $681,222.66 |
| **Qty** | 232 | 371 | 256 | 44 | 39 |
| **UP** | $41,051.00 | $7,833.00 | $72,000.00 | $8,994.00 | $203,199.00 |
| **Authorized** | 209 | 369 | 206 | 45 | 32 |
| **Possessed** | 232 | 371 | 256 | 44 | 39 |
| **Deadlined** | 12.00 | 13.00 | 10.00 | 1.00 | 2.00 |
| **AI** | **0.99** | **0.99** | **0.95** | **1.00** | **0.93** |

**1999**

| | E0330 | E0915 | E0935 | E1911 | E1912 |
|---|---|---|---|---|---|
| **TSC** | $79,519.42 | $126,788.00 | $882,864.45 | $186.70 | $567,722.94 |
| **Qty** | 177 | 375 | 188 | 48 | 33 |
| **UP** | $41,051.00 | $7,833.00 | $72,000.00 | $8,994.00 | $203,199.00 |
| **Authorized** | 182 | 376 | 183 | 49 | 31 |
| **Possessed** | 177 | 375 | 188 | 48 | 33 |
| **Deadlined** | 9.00 | 21.00 | 6.00 | 1.00 | 3.00 |
| **AI** | **0.99** | **0.95** | **0.93** | **1.00** | **0.91** |

**2000**

| | E0330 | E0915 | E0935 | E1911 | E1912 |
|---|---|---|---|---|---|
| **TSC** | $182,685.22 | $50,909.51 | $770,970.07 | $0.00 | $279,731.31 |
| **Qty** | 188 | 407 | 191 | 55 | 47 |
| **UP** | $41,051.00 | $7,833.00 | $72,000.00 | $8,994.00 | $203,199.00 |
| **Authorized** | 199 | 407 | 191 | 56 | 51 |
| **Possessed** | 188 | 407 | 191 | 55 | 47 |
| **Deadlined** | 11.00 | 10.00 | 10.00 | 0.00 | 3.00 |
| **AI** | **0.97** | **0.98** | **0.94** | **1.00** | **0.97** |

**2001**

| | E0330 | E0915 | E0935 | E1911 | E1912 |
|---|---|---|---|---|---|
| **TSC** | $68,415.85 | $31,391.62 | $530,528.50 | $190,133.53 | $3,080.76 |
| **Qty** | 180 | 424 | 193 | 53 | 52 |
| **UP** | $41,051.00 | $7,833.00 | $72,000.00 | $8,994.00 | $203,199.00 |
| **Authorized** | 194 | 418 | 193 | 54 | 53 |
| **Possessed** | 180 | 424 | 193 | 53 | 52 |
| **Deadlined** | 15.00 | 9.00 | 11.00 | 0.00 | 2.00 |
| **AI** | **0.99** | **0.99** | **0.96** | **0.59** | **1.00** |

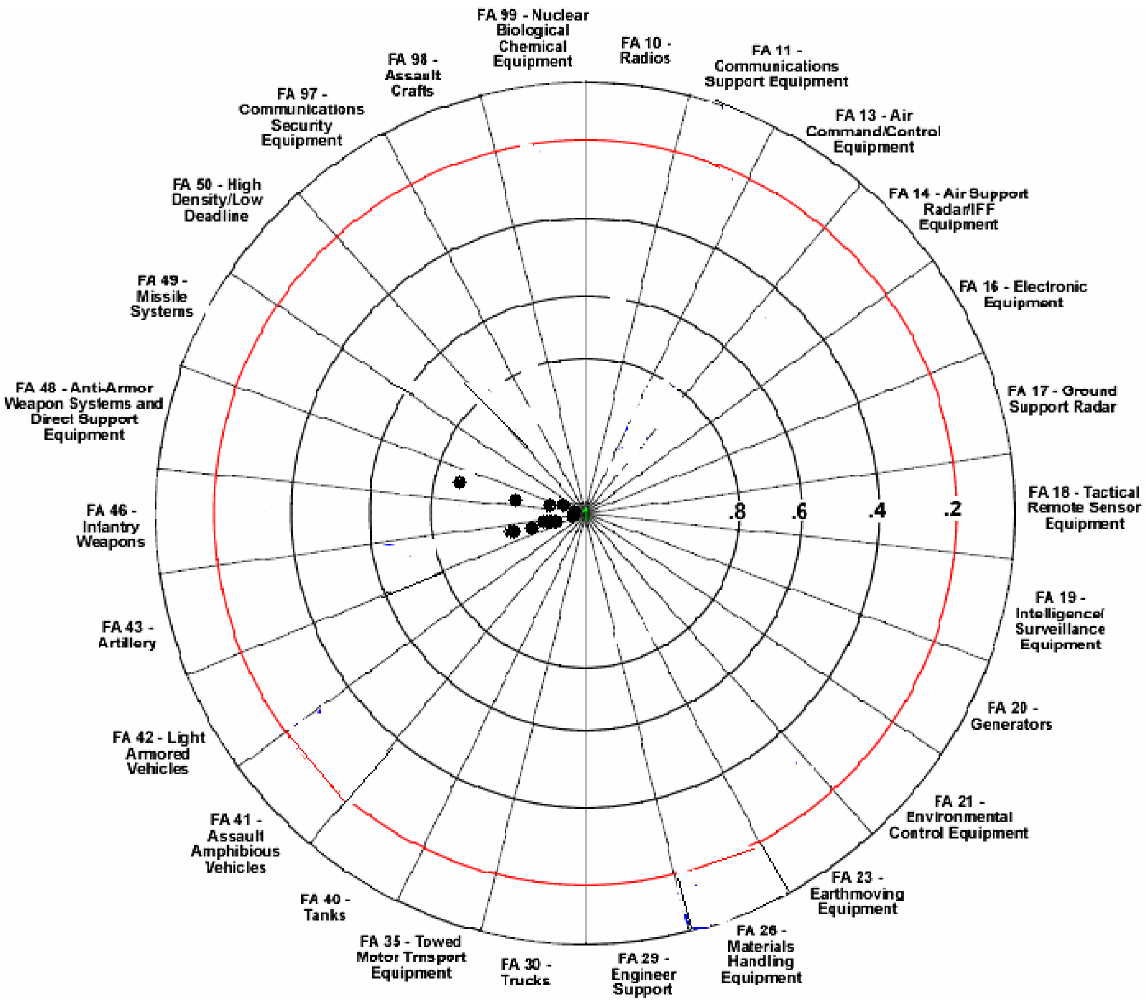
**2002**

| | E0330 | E0915 | E0935 | E1911 | E1912 |
|---|---|---|---|---|---|
| **TSC** | $36,012.31 | $59,376.08 | $593,109.43 | $979.20 | $695,226.38 |
| **Qty** | 201 | 424 | 196 | 54 | 55 |
| **UP** | $41,051.00 | $7,833.00 | $72,000.00 | $8,994.00 | $203,199.00 |
| **Authorized** | 196 | 423 | 196 | 55 | 57 |
| **Possessed** | 201 | 424 | 196 | 54 | 55 |
| **Deadlined** | 14.00 | 17.00 | 15.00 | 1.00 | 5.00 |
| **AI** | **1.00** | **0.98** | **0.95** | **1.00** | **0.93** |

**2003**

| | E0330 | E0915 | E0935 | E1911 | E1912 |
|---|---|---|---|---|---|
| **TSC** | $241,472.76 | $32,001.42 | $1,146,514.80 | $18.30 | $607,063.86 |
| **Qty** | 201 | 411 | 197 | 50 | 54 |
| **UP** | $41,051.00 | $7,833.00 | $72,000.00 | $8,994.00 | $203,199.00 |
| **Authorized** | 203 | 434 | 201 | 54 | 57 |
| **Possessed** | 201 | 411 | 197 | 50 | 54 |
| **Deadlined** | 14.00 | 15.00 | 13.00 | 0.00 | 3.00 |
| **AI** | **0.97** | **0.99** | **0.91** | **1.00** | **0.94** |

Figure 5. Graphical Display of AI Results for FA 43 and FA 48




## D. FINDINGS

From the output of the AI model for FA 43 and FA 48, we conclude that the model does not provide a useful correlation between maintenance spending and readiness level, nor does it provide evidence of a grouping of TAMCNs within a functional area. As seen in Figure 5, the AIs of all TAMCNs are close to one. There is not enough variance in the output to draw useful conclusions. The AI actually paints a false picture of affordability and is not a useful tool for commanders and budgeters to use for the

allocation of scarce resources. That is to say commanders could be misled into making assumptions about the "affordability" of TAMCNs within an FA.

The reason for this is the structure and underlying assumptions about the model, specifically due to the inclusion of Unit Price. The output of the model is not sensitive to items that are deadlined, but rather is sensitive to differences between quantity authorized and possessed. The expected relationship about readiness being a result of maintenance spending does not exist in this formula. In fact, changes in readiness are not reflected in the output, making the result essentially worthless. For example, a TAMCN that has an authorized and possessed quantity of 120 could have 118 items in a deadline status, and still have an AI above .90. See Table 9. For this reason, we feel that this model does not accurately portray what is happening to the TAMCN in the above example in the real world, nor does it represent what is happening within the FA.

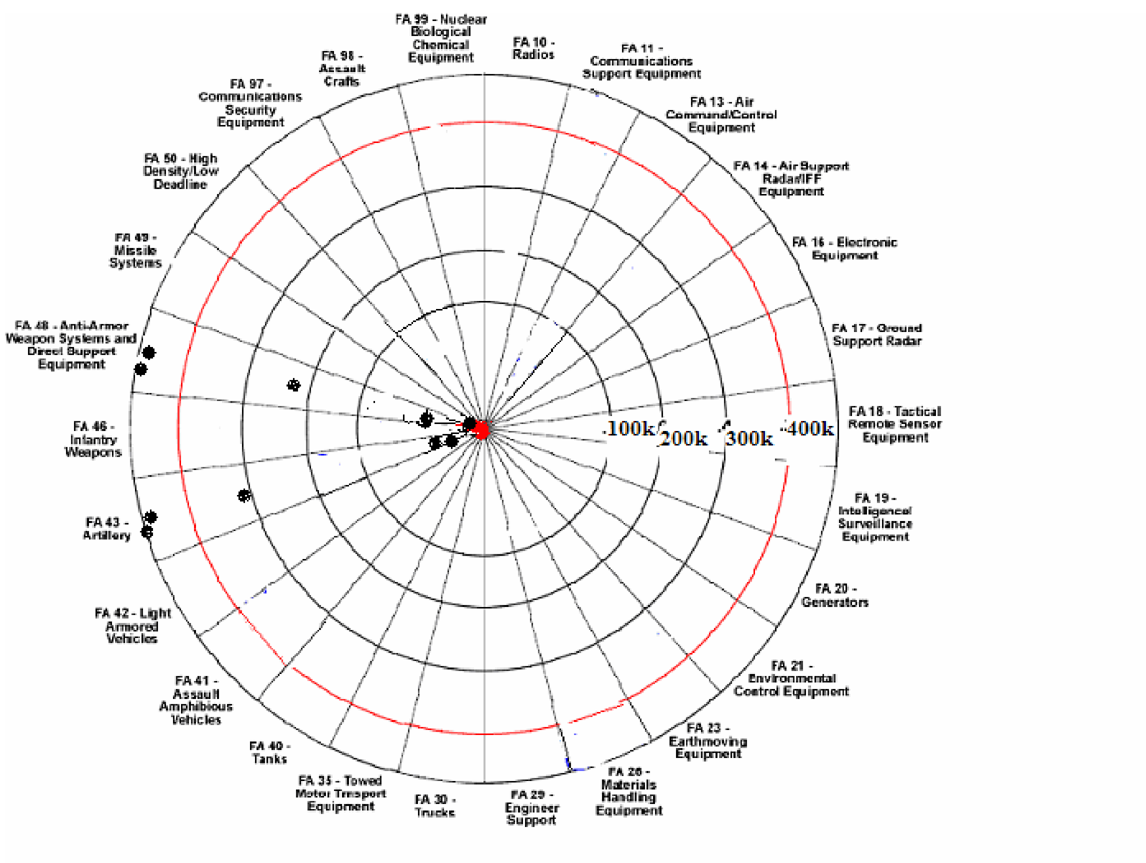
Table 7. Example of High AI With Low Readiness

| E0665 2002 | |
|---|---|
| **TSC** | $310,696.02 |
| **Qty** | 121 |
| **UP** | $1,032,337.00 |
| **Authorized** | 120 |
| **Possessed** | 121 |
| **Deadlined** | 118 |
| **AI** | 0.90 |

The problem is due to the inclusion of Unit Price (UP). The rationale for including UP in the formula was to normalize the data, incorporating the ratio of annual support costs to procurement cost. This was based on the false assumption that annual support costs for all items represent a similar fraction of the procurement price. In reality, the ratio is not at all similar for the various TAMCNs. For example, in 1999, E0915 had annual support costs that were much higher than the original procurement price, 21 were deadlined, but the AI was still 0.95. The conditions seem right for "more attention" in the sense that there are a relatively large proportion of deadlined items but the AI does not reflect it.

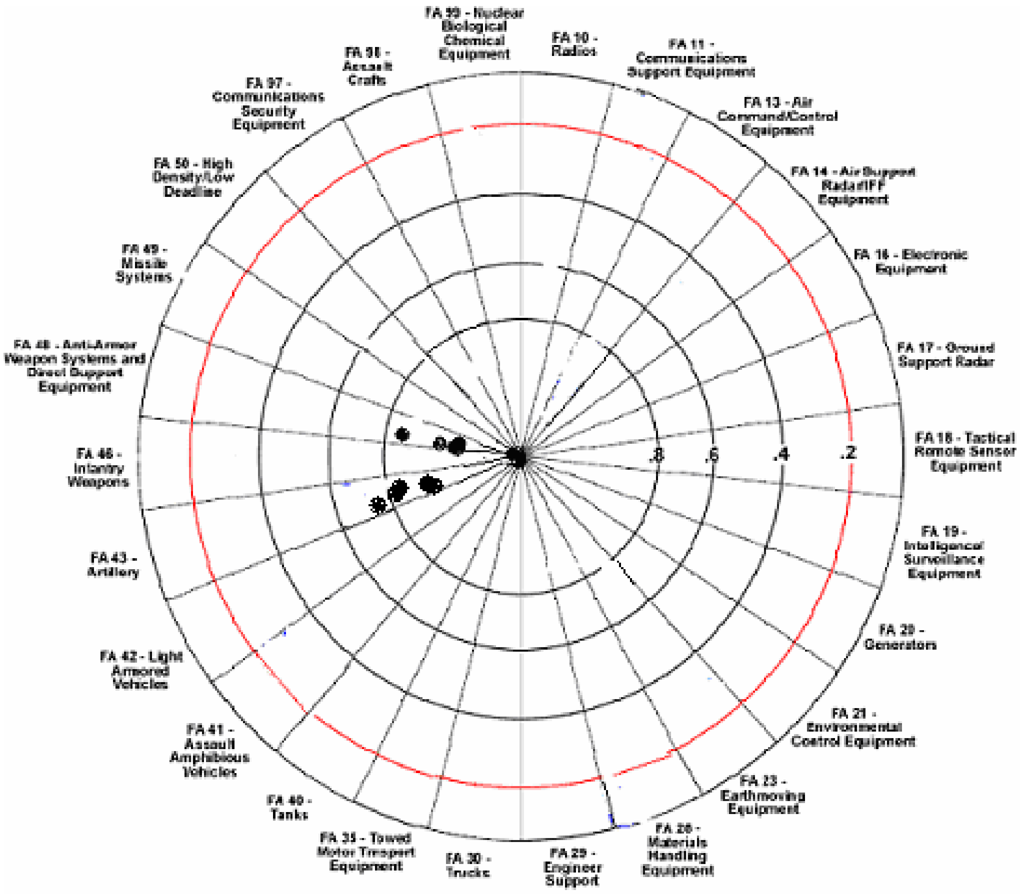
Furthermore, TSC varies greatly between TAMCNs, even within two functional areas. Figure 6, below, displays TSC for all TAMCNs within FA 43 and 48. Annual support cost for these items ranges from $18.00 to $1.5 million. The range in values of TSC combined with varying procurement costs result in an inconsistent ratio that should not be included in the model. The model does not reflect the range of TSC values because of the inclusion of UP.

Figure 6. TSC Values for all TAMCNs within FA 43 and FA 48




Another problem with the AI model is that MR has a very narrow range of values. The objective of the model is to explain fluctuations in readiness level in terms of cost. Readiness, however, does not change greatly over time or by TAMCN. Figure 7 displays MR for all TAMCNs within FA 43 and FA 48. The values are all close to one. In order to more effectively depict changes in MR, the model must either be changed or the range of the graphical depiction refined.

Figure 7. MR Values for all TAMCNs within FA 43 and FA 48




After computing and plotting the AI for all TAMCNs within FA 43 and FA 48 we concluded that the current model is invalid. The model results in output that is close to one in all cases, does not depict changes in MR, and is not sensitive to changes in TSC. Although there are 24 functional areas for Marine Corps' ground combat equipment, there is no reason to compute the AI for all of them. Because the underlying hypothesis and assumptions about the model are unfounded for two unrelated FAs, the results of the

other FAs are irrelevant. If the model does not provide accurate and useful output for every TAMCN and every FA then it is not a good model and should be discarded. In the next section we review and critique each of the variables in the model to further explain the output for FA 43 and 48.

## E. VARIABLE ANALYSIS

In this section we review the variables within the AI model and offer explanations about their use based on our results. We explained the assumptions and rationale for the model above, in section B, with actual output displayed in section C. Because of the problems with the output, particularly that the AI is more sensitive to differences between quantity (authorized and possessed) than it is to deadlined items, we conducted further analysis of the variables themselves and their relationship to the other variables.

The correlation for the variables is as follows:

Table 8. Correlation Data for FA-43

| | *TSC* | *Qty* | *UP* | *Authorized* | *Possessed* | *Deadlined* | *AI* |
|---|---|---|---|---|---|---|---|
| TSC | 1 | | | | | | |
| Qty | 0.733368 | 1 | | | | | |
| UP | -0.01684 | 0.483726 | 1 | | | | |
| Authorized | 0.743423 | 0.99938 | 0.463907 | 1 | | | |
| Possessed | 0.734681 | 0.999984 | 0.482591 | 0.999399037 | 1 | | |
| Deadlined | 0.250049 | 0.734464 | 0.773602 | 0.723337543 | 0.734094707 | 1 | |
| AI | 0.229809 | 0.445382 | 0.484209 | 0.442526756 | 0.445421644 | 0.366982 | 1 |

Table 9. Correlation Data for FA-48

| | *TSC* | *Qty* | *UP* | *Authorized* | *Possessed* | *Deadlined* | *AI* |
|---|---|---|---|---|---|---|---|
| TSC | 1 | | | | | | |
| Qty | -0.09618 | 1 | | | | | |
| UP | 0.496356 | -0.50104 | 1 | | | | |
| Authorized | -0.11547 | 0.995388 | -0.51068 | 1 | | | |
| Possessed | -0.09618 | 1 | -0.50104 | 0.995388069 | 1 | | |
| Deadlined | 0.053289 | 0.835641 | -0.33201 | 0.83768252 | 0.83564106 | 1 | |
| AI | -0.33811 | 0.208636 | -0.16371 | 0.213505804 | 0.208635676 | 0.183399702 | 1 |

If the AI formula was fundamentally sound, we would see a high correlation between the variables. A high level of correlation between variables in a formula means that the variables are strongly related. For variables that have strong correlation with each other, a change in one variable will affect the other. In the case of the AI model, we would expect a similar level correlation between variables regardless of functional area.

The relationship between the variables in the formula should remain stable, regardless of the functional area being analyzed. As show in Tables 10 and 11, however, this is not the case. Unit Price, for example, is negatively correlated with TSC in FA 43 but positively correlated with TSC in FA 48. A negative correlation, such as for FA 43, means that the variables move in opposite directions in relation to each other. As UP increases, TSC decreases and vice versa: as TSC increases or decreases, UP responds in the same way. A positive correlation, on the other hand, means that the variables tend to move in the same direction. One of the assumptions that prompted the inclusion of UP in the model was that UP and TSC have a similar relationship across all FAs. If this were true it would also mean that they were similarly correlated for all FAs. We need look no further than these two FAs to see that this is not the case.

Due to the problems with correlation and mistaken assumptions about the relationship between procurement price and annual support costs, we conclude UP should be omitted from the model. The variable UP represents the unit price or procurement cost of an end item for a particular TAMCN. This number may be relatively large in comparison to the total support cost for its associated TAMCN. For example, the

TAMCN E0665 within FA 43 has a TSC of $792,282.17, while the UP for that item is $1,032,337.00. When the AI model is run, the UP is multiplied by the quantity of E0665's within I and III MEF. By doing so, the AI generates a very large number in comparison to TSC. When placed within the AI model this produces a number close to one regardless of the number of items deadlined. We therefore have to ask the question, what does the unit price tell us about the total support costs in relation to maintaining readiness?

Our conclusion is that the initial procurement price is a sunk cost that should not be incorporated into an analysis seeking to determine future allocation of resources. It was initially included to produce an AI between zero and one, but the unexpected output sends us back to the drawing board for a more effective model. In the next chapter we present a simple readiness-to-cost model and discuss its potential usefulness and applicability as a tool for allocation of maintenance spending.

# VI. RECOMMENDATION FOR A READINESS –TO-COST MODEL

## A. MOTIVATION

As discussed in Chapter II, the Marine Corps is pursuing an enterprise level management tool for tracking maintenance and readiness known as MERIT. MERIT allows MEF and Division commanders to view current and historical materiel readiness (MR) levels and analyze trends. The AI model discussed in Chapter V was intended for use as a module within MERIT to augment the commanders' ability to allocate scarce maintenance resources. In that chapter, we concluded that the proposed AI model does not work as it was intended because of faulty assumptions and unstable relationships between the variables. In this chapter, we explore a materiel readiness-to-cost model that could be incorporated into MERIT to fulfill the goals of the AI. We begin with a conceptual overview of the readiness-to-cost model and present examples of existing tabular data fields within MERIT for material readiness ratings (MR). Next, we discuss the potential applications of the readiness–to-cost model using graphical depictions of the data for the same functional areas we used for our analysis of the AI model. We then conclude our analysis by providing ways in which this model can be improved in the future by including additional costs that have a significant impact on materiel readiness.

## B. OVERVIEW

The readiness-to-cost model presented in this chapter is intended to serve as an alternative approach to fulfill the intent of the AI model. The basis for our recommendation is the belief that a simple readiness-to-cost model is sufficient enough to provide materiel readiness stakeholders with a useful tool for maximizing materiel readiness because it provides a degree of empirical analysis not currently available to them. The model includes a graphical depiction of the relationship between materiel readiness (MR) and total support cost (TSC). Rather than determining the "affordability" of an item, which is more important during the acquisition and replacement phases of the

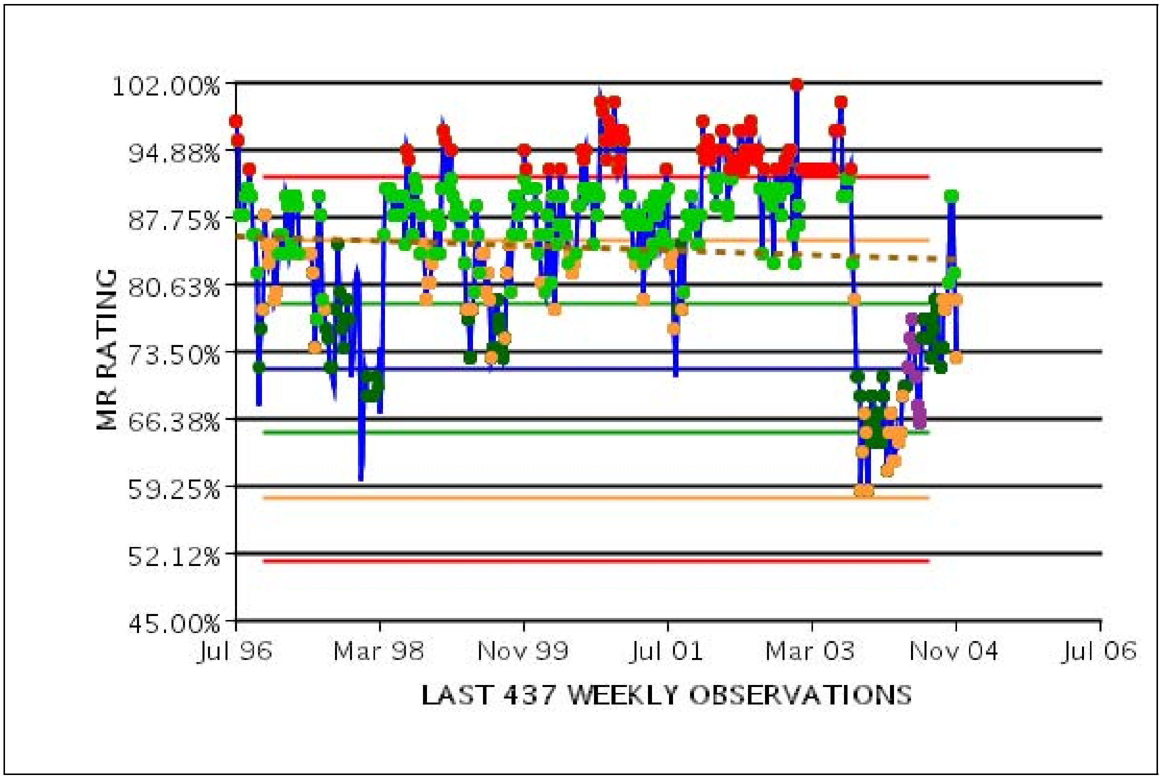
equipment life cycle, the readiness-to-cost model is shown to be more beneficial to materiel readiness stakeholders because it focuses on equipment *sustainability* during the operational phase of the equipment life cycle.

The readiness-to-cost model serves as a measure of the return-on-investment (ROI) from “investing” maintenance funds to sustain and improve materiel readiness. For example, commanders would use the model to improve the sustainability of ground combat principal end items (PEI’s) by analyzing trends and allocating maintenance funds based on which items are the best candidates for maintenance spending. It is also useful as an explanatory tool for spikes or drops in spending. Over the long term, the readiness-to-cost model is an effective tool for examining the cyclical nature of maintenance spending. Because the cyclical nature of maintenance spans many years, the scope of our current analysis is somewhat limited by the fact that our data set contains only eight years of maintenance and cost data.

Ideally, the readiness-to-cost model will be incorporated into MERIT. As discussed in Chapter II, MERIT is extremely versatile and user-friendly. It has many tools which may be tailored by materiel readiness stakeholders to analyze the current status and historical trends of maintenance and readiness levels. Users can access tabular data fields, import the fields into Excel for ad hoc analysis, and view charts and graphs of readiness levels over time. They can customize the output by unit as well as timeframe.

The following figures, Figure 8 and Figure 9, are actual examples of output displays in MERIT. They are included to illustrate the usability and visual nature of the output and are examples of the tabular data from MERIT. Figure 8 depicts MR data and trend analysis for all M1A1 tanks in I MEF over the last 437 weeks. Figure 9 is another example of tabular data that can be used to conduct trend analysis of material readiness rating (MR) for a specific period of time. In this instance, the chart represents the same TAMCN and MEF as in Figure 8, but includes 52 weeks rather than 437 weeks of data. The result is a more detailed graph that reflects current trends.

Figure 8. MERIT tabular output: MR trend over last 437 weeks




Data

A(+/-) line indicating three standard deviations from the historical mean MR rating.

B(+/-) line indicating two standard deviations from the historical mean MR rating.

C(+/-) line indicating one standard deviation from the historical mean MR rating.

The historical mean MR rating.

The MR trend line for the most recent 437 weeks.

Rule 1 Detection: Occurs when a point exceeds the control limit of three standard deviations from the mean (A). Also known as an extreme outlier.

Rule 2 Detection: Occurs when 2 out of 3 consecutive points are beyond two standard deviations from the mean (B) and are on the same side of the mean.

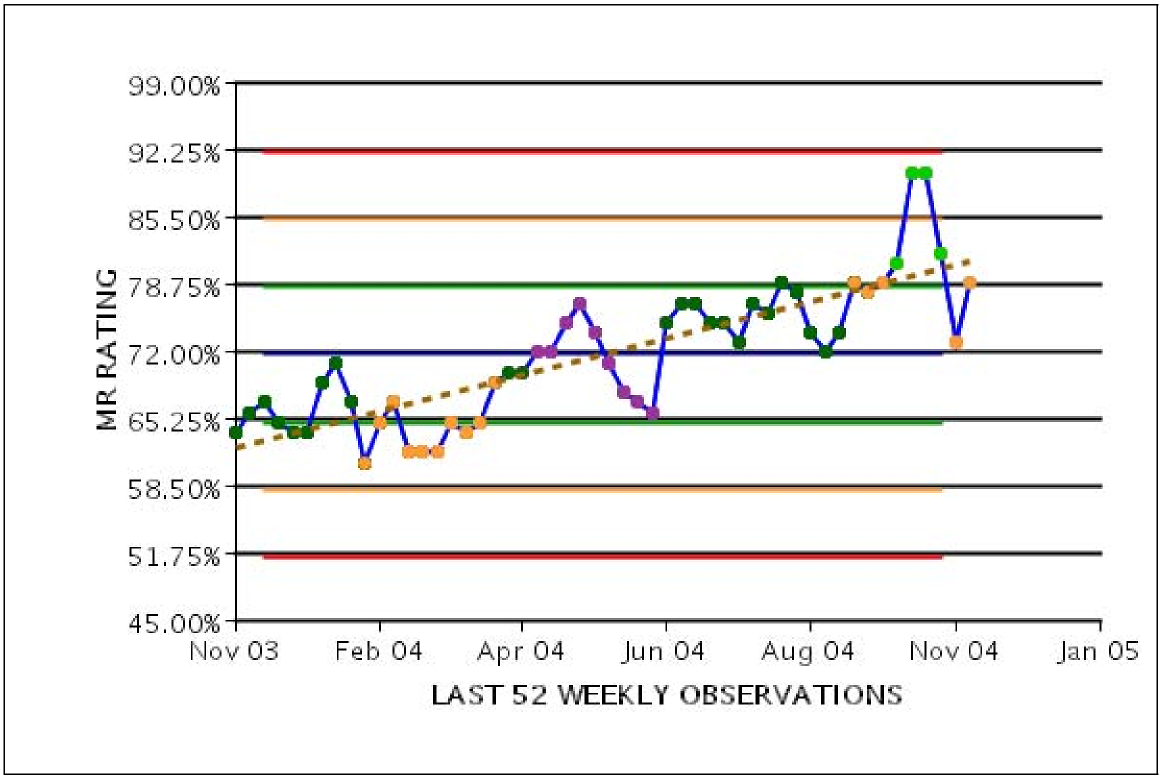
Rule 3 Detection: Occurs when 4 out of 5 consecutive points are beyond one standard deviation from the mean (C) and are on the same side of the mean.

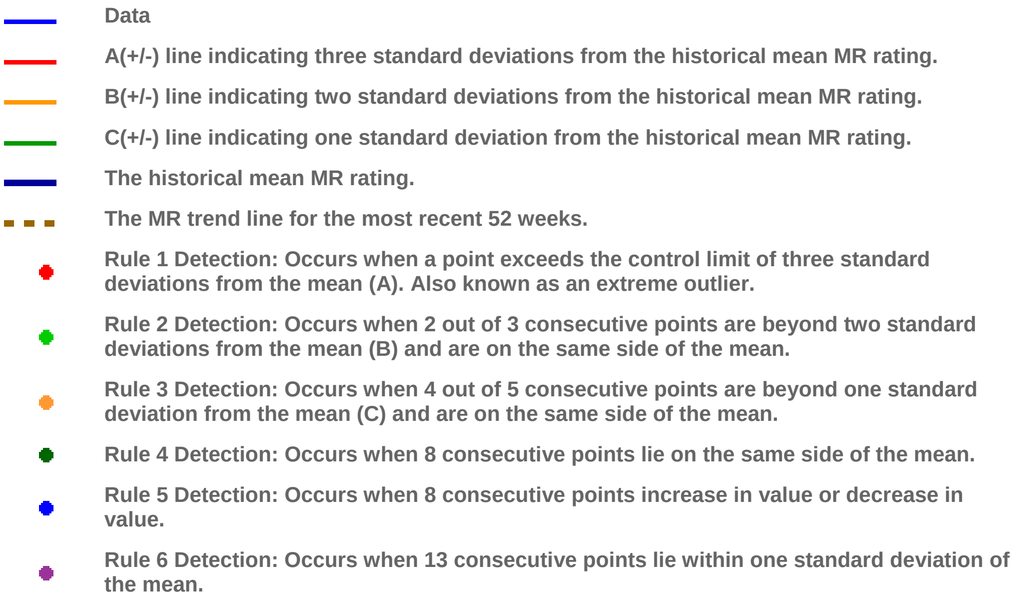
Rule 4 Detection: Occurs when 8 consecutive points lie on the same side of the mean.

Rule 5 Detection: Occurs when 8 consecutive points increase in value or decrease in value.

Rule 6 Detection: Occurs when 13 consecutive points lie within one standard deviation of the mean.

Figure 9. MERIT tabular output: MR trend over last 52 weeks



The metrics listed in Figure 8 and Figure 9 utilize the mean and standard deviation of materiel readiness data. We conclude from applying the metrics in Figure 9 that the points above and below the mean are not just isolated events. This is particularly useful for maintenance planning, because we can look at trends over time and ask why the MR was behaving in a particular way. In doing so, we may find, for example, that units were deployed, training, or in garrison. The ability to view the behavior of MR during these scenarios can aid in the maintenance planning for units that will be using that system in a similar manner and environment.

The readiness-to-cost model can eventually be incorporated into MERIT and displayed in similar tabular data fields to show trends over time. In addition to viewing readiness-to-cost over time, similar metrics as those for MR trend analysis as described above in Figure 8 and Figure 9 could be applied, and analyzed in a similar manner. In the next section we describe the readiness-to-cost model and provide specific examples of its applicability to materiel readiness analysis.

## C. ANALYSIS OF READINESS-TO-COST MODEL

As more and more data becomes available, the output of the readiness-to-cost model will become more useful and valuable. By examining long-term, analysts will be able to view the cyclical nature of equipment readiness and maintenance spending. More data will also facilitate studies on the mean time between failure (MTBF) of systems. Analyzing MTBF shows the actual availability and reliability of systems rather than what they were predicted to be during the acquisition process. MTBF studies also provide a heuristic for whether or not we got what we paid for when we purchased the item. ROI and MTBF studies are useful for determining which systems to enter into service life extension programs (SLEP), initiating contractor bids for replacement systems, or establishing performance based logistics (PBL) contracts for intermediate and depot level maintenance.

The readiness-to-cost model provides a visual display of readiness-to-cost for a particular TAMCN over a period of time. Analyzing data over a long period of time yields more useful results than shorter time spans, particularly in conducting trend

analysis. Eight years is a relatively short timeframe when considering the overall life of most weapons systems. By looking at only eight years of data, our results are quite erratic and require further refinement to increase their usability. The initial output of readiness-to-cost had extreme variability. The impetus of the readiness-to-cost model is to provide a quick, visual map of problem areas. Extreme deviations should be the exception rather than the rule if the model is to be useful as a quick visual reference. To achieve more user-friendly results, we had to eliminate some of the extreme variability in the graphs.

To "smooth" the data and make it easier to identify areas of concern, we first calculated the average values of MR and TSC over the eight year time period. We then calculated a two-year moving average and normalized the results with the eight year average. The result was a much smaller range of output, but it needed another minor refinement to be more visually appealing and easily readable. We then calculated readiness-to-cost using the normalized figures. To narrow the range of values even further, we calculated the square root for the normalized MR, TSC, and readiness-to-cost. The result was a visual display that enabled easier identification of areas of concern than the initial non-normalized display.

The following figures are actual results from the normalized readiness-to-cost model. They reflect a sampling of TAMCNs from several FAs. The output is not a purely quantifiable measure of affordability or return-on-investment, but it does provide a systematic and consistent means of analyzing trends. Rather than determining the affordability of an item, the readiness-to-cost output is used as an indicator for areas of concern that require further research or management attention. In the interest of sustaining ground combat equipment that is already in use, the readiness-to-cost model creates a record of performance and a roadmap for change.

The following figures graphically display the output from the readiness-to-cost model. In addition to displaying readiness-to-cost, we also display MR, TSC, and the linear trend line for readiness-to-cost. Once we prepared the charts, we asked ourselves the question: "What do these graphs tell us about the return-on-investment of maintenance spending?"

Figure 10. Readiness-to-cost output for A1935: MRC-138B

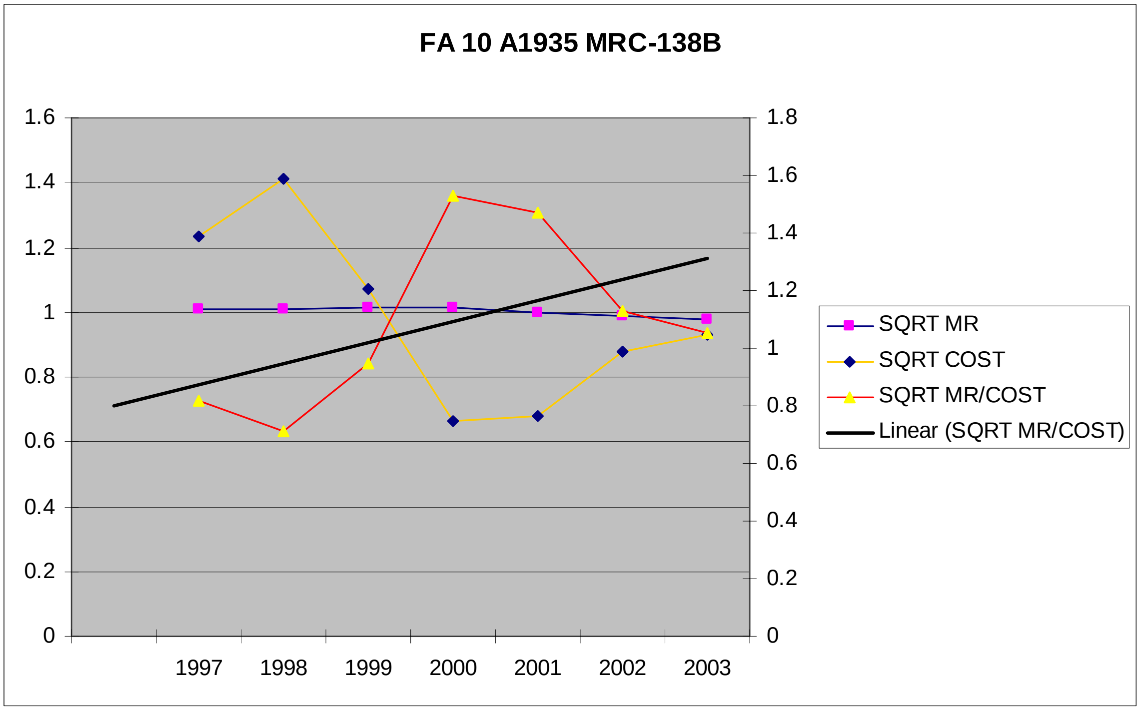



Figure 11. Readiness-to-cost output for B0921: Generator Set MEP-813A/805A

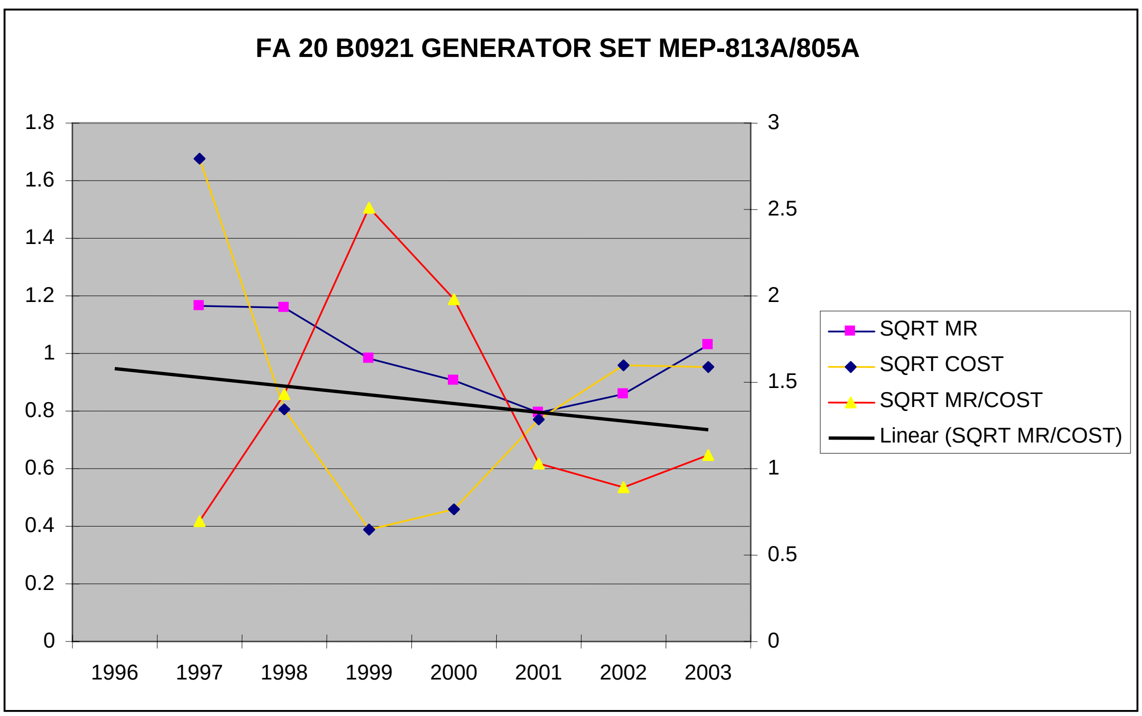


Figure 12. Readiness-to-cost output for D1125: HMMWV TOW Carrier

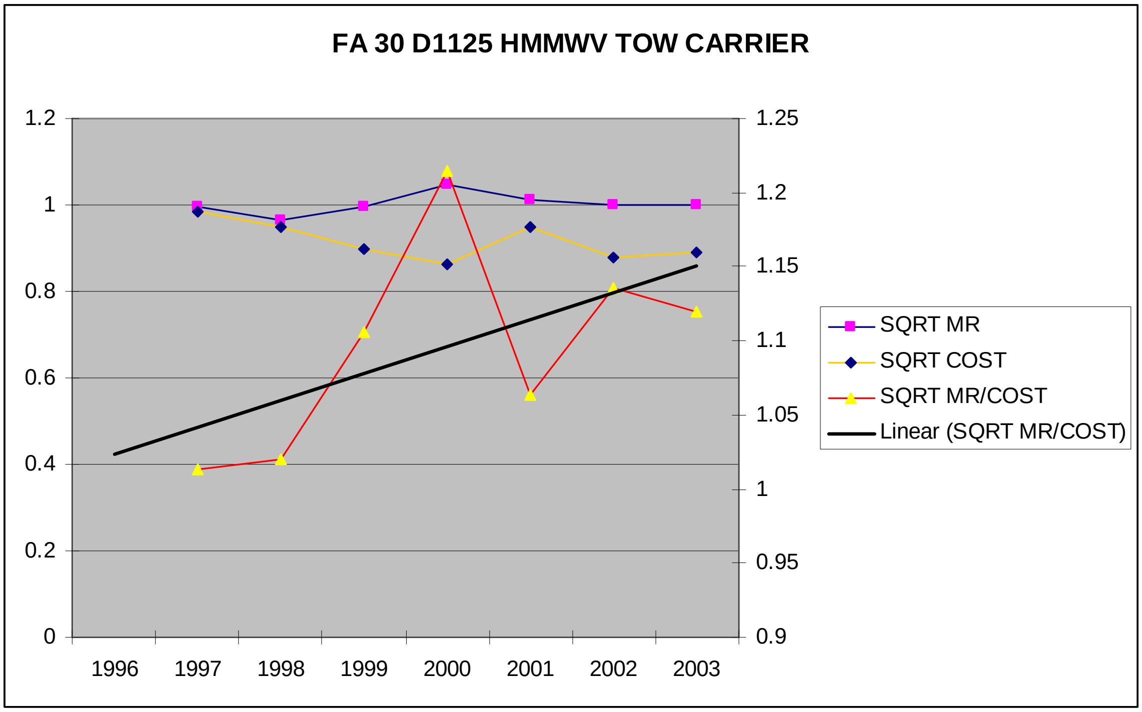



Figure 13. Readiness-to-cost output for D1059: 5-ton Cargo Truck 6x6

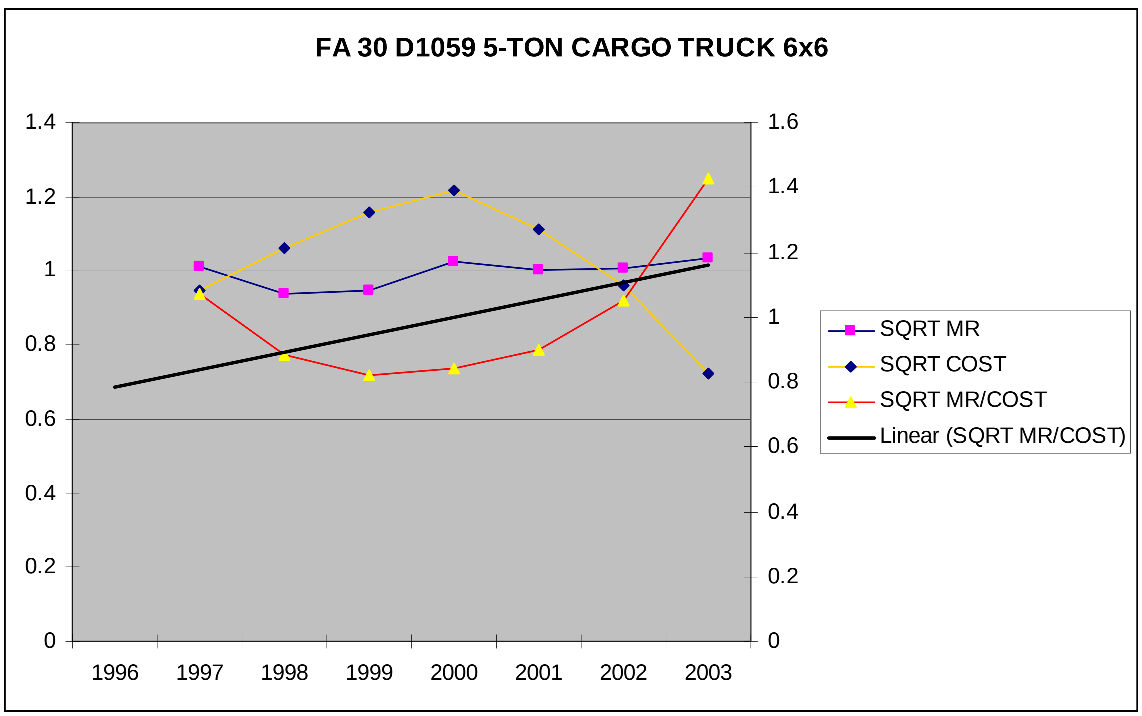


Figure 14. Readiness-to-cost output for E0935: M220E4 TOW

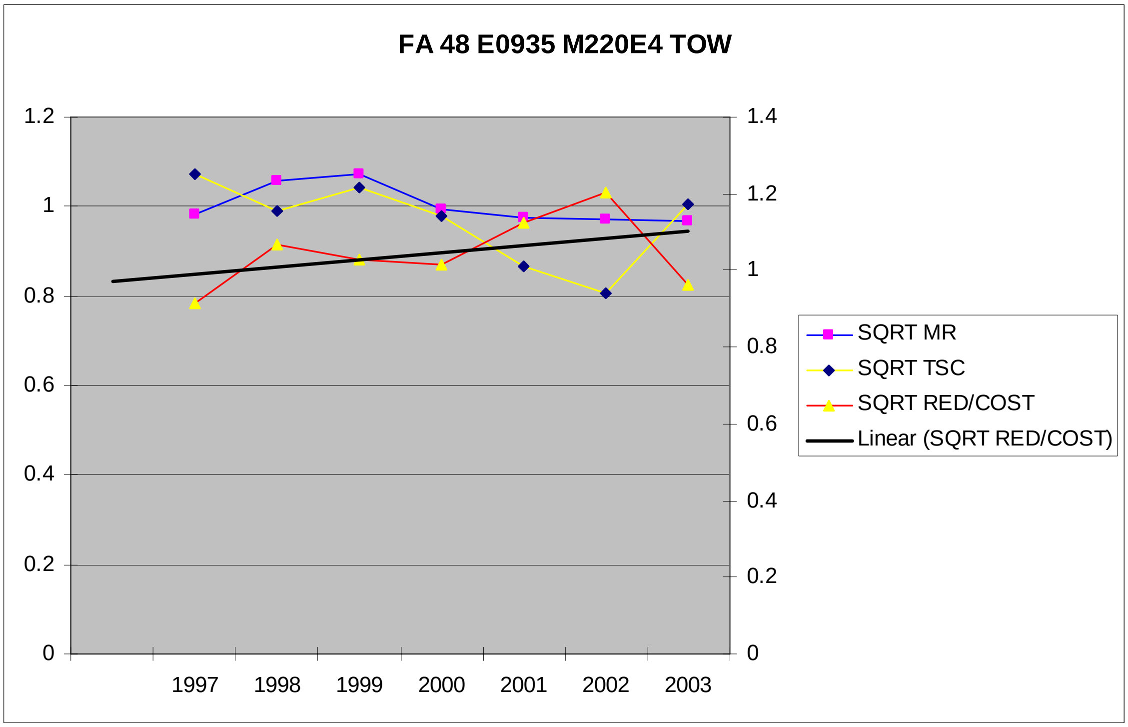



Figure 15. Readiness-to-cost output for AN/UAS-12A/C Night Vision Equipment Set

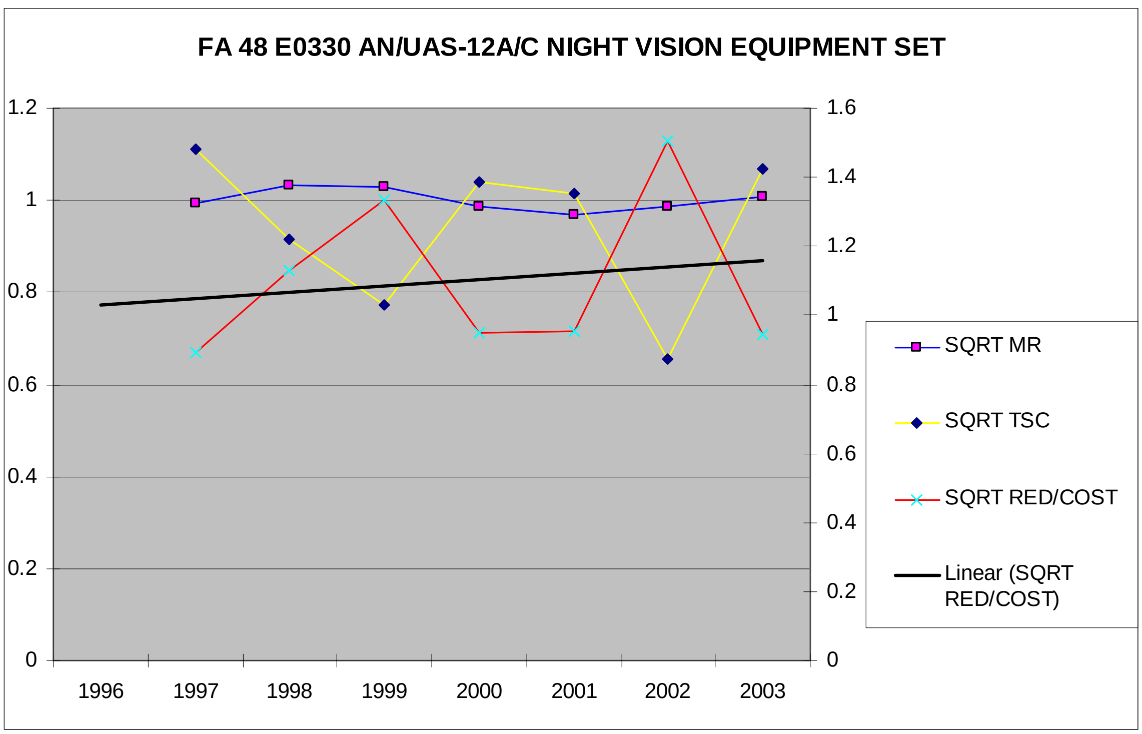
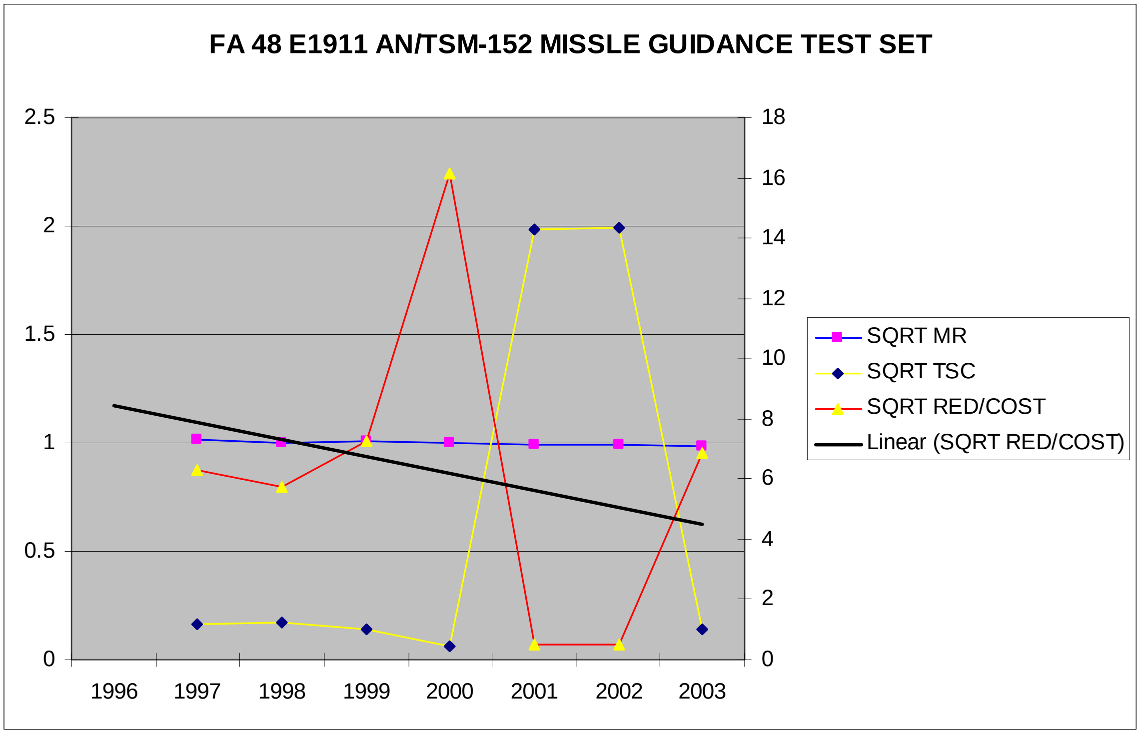


Figure 16. Readiness-to-cost output for E1911: AN/TSM-152 Missile Guidance Test Set




We also scrutinized the MR and TSC lines. In all cases, the MR remained very stable-- regardless of the readiness-to-cost and TSC lines. In some cases, the MR was greater than one, meaning a unit has materiel readiness greater than 100%. This can only occur when a unit has excess equipment in its inventory. Although MR is a commanders "go to war" capability, we are looking for the direct effect of maintenance spending on an item's readiness level. MR is not restricted to values between zero and one because it includes Quantity Possessed and Quantity Authorized. If units have more items on hand than they are authorized, their MR increases. The result is the incentive to hold excess equipment. The result may or may not be higher spending for maintenance, but it creates the possible problem of artificially inflated or artificially stabilized MR levels.

The problem of sable MR levels remains. That is, why is MR almost always constant when readiness-to-cost is relatively low and high? It is because MR is not sensitive to changes in spending. It stays within a small range regardless of the spending level. Perhaps our proxy measure of TSC, deadlining parts cost, does not present a useful measure of maintenance costs. Perhaps MR is not a good measure of return-on-

investment of maintenance spending because of the inclusion of Quantity Possessed and Quantity Authorized. We conclude that the readiness-to-cost model requires further refinement before it can be incorporated into MERIT as a resource allocation tool. In the next section we present further analysis of the readiness-to-cost model by addressing the problem of incomplete cost data and explore the alternative of using R rather than MR as a measure of material readiness.

## D. REFINEMENT OF READINESS-TO-COST MODEL

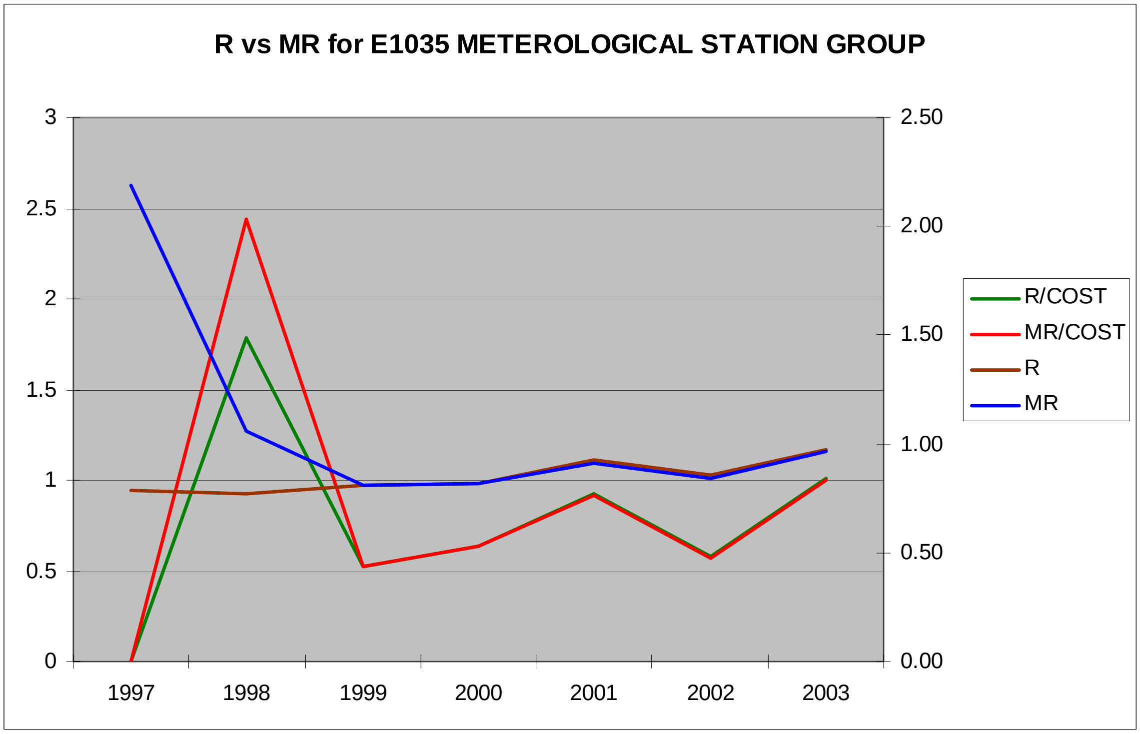
In the previous section we examined the output from a basic readiness-to-cost model and discovered questions about its structure. In this section we examine the effect of replacing MR with R in the readiness-to-cost model. This improvement is required to answer the question about the sensitivity of readiness to spending levels. We present graphical outputs of readiness (R) to cost as an alternative to MR and analyze their usefulness.

The AI model used MR to reflect materiel readiness. In Chapter V, we defined MR in terms of the variables: (Quantity Possessed – Quantity Deadlined) / Quantity Authorized. In reality, using MR as a metric for readiness rewards commanders for holding excess items. This results in an upward bias of the true maintenance readiness. To be consistent with the AI, we used MR in the readiness-to-cost model. Rather than using MR, we believe R may be a more effective measure of readiness because it does not include the upward bias associated with Quantity Possessed and Quantity Authorized. Our contention is that using R would present a more accurate depiction of a systems' readiness posture.

Figure 17 depicts the R-to-cost versus the MR-to-cost of a system. We selected E1035, Meteorological Station Group, to test the effect of using R because it had an MR greater than one during the first year. We used the same data normalization methods that we used for the graph in the previous section in order to ensure an accurate comparison. Of particular interest in this display is the difference in MR and R. MR decreases into steady state while R increases only slightly into steady state. Any decrease in readiness reporting may lead commanders into believing that they have lost capability. When we

report R, this statement is true. However, when we report MR, this statement may not be true. In Figure 17 we see that the true system readiness is nearly at 100%. If the commander had viewed his true readiness using MR, he would have falsely assumed that he had a degraded readiness posture. Additionally, the use of MR caused a greater spike in readiness-to-cost vice the true readiness-to-cost ratio that exists when we use R.

Figure 17. R vs. MR for E1035: Meteorological Station Group




The line for R is somewhat more sensitive than MR but is still relatively stable. Like MR, R is not particularly sensitive to changes in spending. The output of this second readiness-to-cost model provides a means of viewing changes in cost and changes in readiness but does not explain changes in readiness as a function of cost. We cannot establish a causal relationship between the minor fluctuations in readiness and the large variation in cost.

After determining that using R in place of MR in a readiness-to-cost model still does not provide an effective tool for analyzing the relationship between cost and readiness in the interest of allocating maintenance resources, we reviewed what

comprises cost. We are only using repair parts costs for this analysis, but there are other costs that must be captured to accurately reflect total support cost. In the next section we provide recommendations for the future development of a cost analysis model.

## E. RECOMMENDATIONS FOR FUTURE APPLICATIONS

The motivation to create the Affordability Index and the readiness-to-cost model is to establish a quantifiable measure of how well systems are performing. Immense effort goes into the acquisition, testing and evaluation, and fielding of equipment, but materiel readiness managers are still required to measure and evaluate the performance of existing equipment. The AI and the readiness-to-cost model are attempts to provide a solution by examining the direct relationship between cost and readiness. In reality, readiness levels do not fluctuate a great deal. As systems age, their readiness is preserved, perhaps not by more parts but by longer hours and more effort on the part of the mechanics.

In either case, it is difficult to isolate one particular variable that is driving readiness levels. Rather than examining readiness as a measure of effectiveness of equipment, perhaps we should limit our analysis solely to cost. In keeping with the spirit of the Affordability Index, commanders could examine items with rising cost to evaluate their current and future affordability. They could drill down further to analyze the cost behavior of system components and replacement parts to determine what are the actual cost drivers within existing and aging systems.

What does a spike in repair parts costs tell us? Ideally we would have accurate and complete information about all the cost drivers to compile an accurate and complete measure of TSC. In reality, however, we do not have accurate and complete information, which is why we used deadlining parts cost as a proxy for TSC. By continuing to use deadlining parts cost, we offer that we can use the spikes in TSC to evaluate the MTBF of systems by drilling down the repair parts costs. We constructed a pivot table for the severe spike in TSC in Figure 17. We asked ourselves whether there were many parts that broke, or a single part that broke repeatedly to drive the cost. Table 10 is a pivot

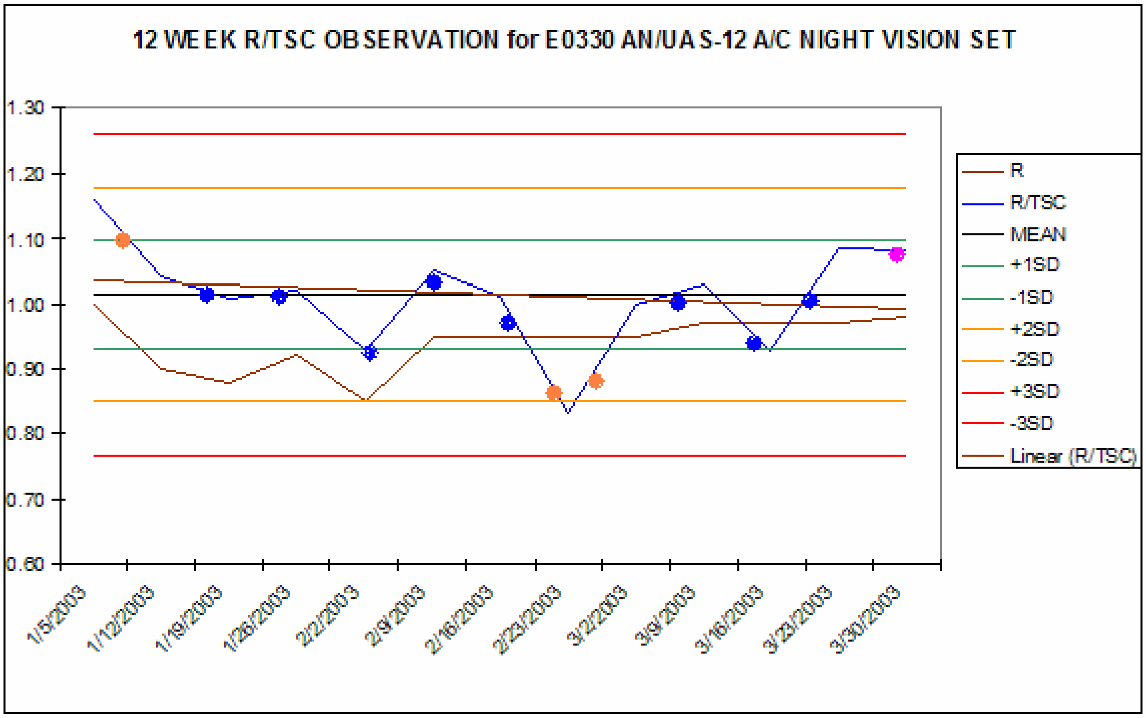
table that answers this question. From this table, we can see that there were two repair parts that cost approximately $190,000, and made up 99% of the repair parts cost for the duration of the spike in TSC from 2001 – 2002.

Table 10. Pivot table output: cost summary for E1035: Meteorological Station Group

| PART NAME | PARTS CHARGE | QUANTITY REQUIRED | % OF PARTS COST |
|---|---|---|---|
| CASE,FIELD | 214.98 | 1 | 0.11% |
| COVER,ELEC | 6.04 | 1 | 0.00% |
| EYESHIELD, | 34.28 | 1 | 0.02% |
| FUSE,CARTR | 0.34 | 1 | 0.00% |
| LAMP,CARTR | 13.17 | 3 | 0.01% |
| LIGHT,INDI | 11.22 | 3 | 0.01% |
| MISSILE GU | 30,597 | 1 | 16.01% |
| POWER SUPP | 527.51 | 1 | 0.28% |
| PROPELLER | 214 | 1 | 0.11% |
| SWITCH,TOG | 13.63 | 1 | 0.01% |
| TEST CONTR | 159,312 | 1 | 83.36% |
| WIRED HOUS | 168.56 | 1 | 0.09% |
| **Grand Total** | **$191112.73** | **16** | **100%** |

We see the potential that our model has, and we show the reader in Figure 18 using actual readiness data, and notional cost data how our model can be used in MERIT. Figure 18 displays 12 week observation of readiness data, and notional cost data for an AN/UAS 12 A/C Night Vision Equipment Set (E0330) within FA 48. We broke the data down into weekly segments in order to get a more detailed view of how readiness-to-cost is behaving. We also utilized the rules within MERIT to show its use.

Figure 18. Notional display of readiness-to-cost of E0330: AN/UAS 12 A/C Night Vision Equipment




When we apply the rules that currently exist in MERIT, we can see that this system is relatively stable for this 12 week period. Ideally, readiness-to-cost would be applied within MERIT in a manner similar to this. We could also use pivot tables to drill down and inquire about spikes. We showed how this could be accomplished in Figure 18. This may provide us with part of the explanation about the spike in readiness-to-cost. There may also be other factors that adversely affect cost that we are not capturing in this model. We mentioned in the analysis that parts cost may not be an adequate representation of total support cost. There are other costs that need to be captured in order to represent the full spectrum of TSC. Costs such as labor hours, shop overhead for all three levels of maintenance, transportation costs associated with sending systems and components to higher levels of maintenance need to be captured. When combined, these

costs have been shown to effect maintenance planning for organizations such as NAVAIR. We have studied the maintenance costs and logistic strategy of NAVAIR in our Logistics Strategy course. This has provided us with an insight into capturing the true TSC ground combat equipment. We believe that if we can view the costs associated with these areas, we can improve the overall maintenance cycle and readiness of our systems.

# VII. CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

## A. MOTIVATION

The time for developing a tool to track the maintenance costs associated with material readiness is at hand. As our current inventory of ground combat equipment continues to age, and as new and more technologically sophisticated systems are acquired, we need to know how much it costs to maintain material readiness in order to budget maintenance funds and apply scarce maintenance resources. Such a tool must be developed now in anticipation of ever-shrinking budgets and scarce resources. The Secretary of Defense has established a culture of transformation for the military, one in which we take advantage of best business practices and streamline our operations by performing functions such as maintenance more efficiently.

One proposed method of analyzing the relationship between cost and readiness is the Affordability Index model developed by Marine Corps Logistics Command (LOGCOM). The purpose of this project was to analyze the AI model and to provide an alternative proposed method of analyzing cost and readiness. This chapter begins with an overview of our project. We first provide the reasons why the Marine Corps needs a tool such as the AI. Next we summarize our research and highlight our findings on the analysis of the AI and readiness-to-cost models. Finally we conclude with a recommendation for further development of the readiness-to-cost model as an alternative solution to the AI model and as a proposed module in MERIT.

## B. OVERVIEW

The Marine Corps lacks a tool that links maintenance costs to the material readiness of ground combat equipment. Our research commenced with the introduction of the Affordability Index model developed by LOGCOM. Our analysis of the AI started with a review of the Marine Corps current practice of tracking maintenance costs and material readiness. The current practice of tracking material readiness is decentralized and uses various unrelated IT systems. MERIT incorporates the maintenance data from the legacy systems but does not provide accurate or complete cost data. It also lacks a

means of linking cost and readiness. The current practice for tracking support costs is disjointed and antiquated. As detailed in Chapter II, the Marine Corps uses MIMMS and SASSY to track all maintenance records and costs, which lack sufficient information for calculating components such as labor cost, facilities costs, and overhead. Support costs beyond those associated with repair parts are not accurately captured or reported.

To conduct an analysis of the AI, we ran the model with data pertaining to both maintenance and materiel readiness. We used eight years of historical data that were obtained from MIMMS and SASSY. Our first task was to cleanse the data and mold it into a useable form that could be run through the AI model. We set out on this task by developing heuristics to reduce the size of the data sets and by applying current rules for reporting the MR of MARES items. Once all of the data were inputted into the model, we were able to view the results and make conclusions and inferences about the usefulness of the AI. The first observation that we made was that the AI did not behave as LOGCOM had intended it to. For example, the AI was supposed to work on a scale between zero and one with one being the best outcome. Our tests produced results that were close to one for almost all of the items that we ran through the model.

Further analysis revealed that the AI was not sensitive to deadlined items, but that it was more sensitive to differences in the quantities of items authorized and possessed. We concluded that the AI would paint a false picture of affordability, because its design had the potential to mislead commanders about the true state of their equipment. We provided an example of this type of error in Chapter V. We determined that this was a result of the insensitive nature of the model. The use of the variable UP biased the results upward for all of the TAMCNs that we analyzed. We concluded that this state exists because of the magnitude of UP multiplied by quantity of the active fleet in comparison to TSC. We concluded chapter V with a recommendation to analyze a readiness-to-cost model.

We initiated our recommendation for a readiness-to-cost model in Chapter VI first by using the existing variables of MR and TSC from the AI model. We used MR and TSC to calculate readiness-to-cost, and present a graphical display. Our motivation for using a graphical portrayal of readiness-to-cost was to satisfy the end-state of the AI

model by showing ROI, and to provide a useful tool to maintainers and commanders that would enable them to improve system sustainability. Our initial results prompted us to study the use of readiness (R) vice MR. The impetus to use R was primarily based on the fact that MR reflects supply data and rewards commanders with higher readiness levels if they possess excess systems. We concluded that by using R we can portray a more accurate representation of maintenance costs and the resultant level of equipment readiness. In addition to using R, we determined that the variable TSC was not a good indicator of total support costs. We concluded Chapter VI with recommendations for further study on this variable and on improving the readiness-to-cost model.

## C. AREAS FOR FUTURE STUDY

In its present form, the readiness-to-cost model presents only systems readiness and maintenance repair parts cost data. In order to accurately portray support cost, continued study needs to be done on how the Marine Corps can best capture all the elements of support cost. We have recognized that by introducing a more robust cost variable into this model, stakeholders will be able to make better improvements on maintenance spending and readiness. Perhaps a complete analysis of cost cannot be incorporated until new systems are fielded.

In Chapter VI we noted that the readiness-to-cost model could and should be incorporated into MERIT. This endeavor could be greatly assisted with the efforts of students enrolled in the Information Technology Management (ITM) curriculum in conjunction with LOGCOM. In doing so, the model could be constructed to enable drill down analysis that is tailored to the users needs and be aligned with the current maintenance and readiness modules already in MERIT.

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# APPENDIX A: LIST OF ACRONYMS/ABBREVIATIONS

| | |
|---|---|
| ATLASSII+: | Asset Tracking for Logistics and Supply System, Phase II Plus |
| Cat: | Maintenance Category Code |
| ERO: | Equipment Repair Order |
| FMF: | Fleet Marine Force |
| LOGCOM: | Logistics Command |
| MARES: | Marine Corps Automated Readiness Evaluation System |
| McBul: | Marine Corps Bulletin |
| MCO: | Marine Corps Order |
| MEF: | Marine Expeditionary Force |
| MIMMS: | Marine Corps Integrated Maintenance Management System |
| NSN: | National Stock Number |
| SECREP: | Secondary Reparable |
| SL-3 | Shopping List-3 |
| TAMCN: | Table of Authorized Control Number |

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# APPENDIX B: MARES REPORTABLE TAMCNS

| TAMCN | FA | Item |
|---|---|---|
| A0010 | 13 | Air Mobile, DASC, AN/UYQ-3A(V)2 |
| A0011 | 13 | Fire Support Command & Control System (FSCCS), AN/UYK-102 (V)1 |
| A0013 | 13 | Theater Battle Management Core System AN/TYY-2 |
| A0021 | 13 | Multi-Source Correlations System, AN/TYQ-101 |
| A0025 | 13 | Communications Platform, Air Defense (ADCP) |
| A0248 | 11 | Central Office, Telephone Automatic, AN/TTC-42(V) |
| A0274 | 10 | Communications Central, AN/TSC-120 |
| A0283 | 19 | Team Portable Communications System, AN/PSQ-9 |
| A0412 | 19 | Communications Jamming System, AN/ULQ-19(V)1 |
| A0465 | 14 | Decoder Group, AN/UPA-60(V)2 |
| A0499 | 11 | Digital Technical Control (DTC) Facility AN/TSQ-227 |
| A0655 | 10 | Satellite Communications Terminal, AN/TSC-96A |
| A0812 | 10 | Ground Mobile Force Satellite Communications Terminal, AN/TSC-85A/B |
| A0814 | 10 | Communications Terminal, AN/TSC-93B(V)1 |
| A0821 | 13 | Communications Central, Air Support (CASC), AN/TSQ-207 |
| A0873 | 13 | Intel OPS (IOS-INTEL) Server AN/UYQ 91(V) 2 |
| A0881 | 14 | Interrogator Set, AN/UPX-27 |
| A0918 | 10 | Radio Set, Satellite, Tactical, Portable, AN/PSC-5 |
| A0966 | 19 | Mobile EW Support System, AN/MLQ-36 |
| A1010 | 19 | MEF Intel Analysis Suite, AN/MYQ-7 |
| A1219 | 19 | Radio Recon, SS-2 |
| A1221 | 18 | Monitor, Portable, AN/USQ-121 |
| A1310 | 10 | Quick Reaction Satellite Antenna, OE-361G(V)2 |
| A1410 | 14 | Radar Set, Acquisition, Continuous Wave, (CWAR) |
| A1440 | 14 | Radar Set, Fire Finder, AN/TPQ-36(V)5 |
| A1500 | 14 | Radar Set, AN/TPS-63B |
| A1503 | 14 | Radar Set, LW3D, AN/TPS-59(V)(3) |
| A1520 | 19 | Radar System Attack Target JT, AN/TSQ-179B(V)2 |
| A1530 | 16 | Multifunctional Radar Transponder Beacon, AN/PPN-19(V)2 |
| A1795 | 10 | Radio Set, AN/GRC-193B(V) |
| A1818 | 10 | Radio Set, AN/GRC-171B(V)4 |
| A1935 | 10 | Radio Set, MRC-138B(V) |
| A1954 | 10 | Radio Terminal Set, AN/MRC-142B |
| A1955 | 10 | Radio Terminal Set, AN/MRC-142 |
| A1957 | 10 | Radio Set, AN/MRC-145A |
| A2042 | 10 | High Frequency Manpack Radio AN/PRC-138, AN/PRC-150 |
| A2065 | 10 | Radio Set, AN/PRC-104B(V) |
| A2069 | 10 | Radio Set, AN/PRC-113(V)3 |
| A2070 | 50 | Radio Set, Manpack, AN/PRC-119/A |
| A2073 | 50 | Radio Set, Manpack, AN/PRC-119D |
| A2074 | 50 | Radio Set, Vehicular AN/VRC-88D |
| A2075 | 50 | Radio Set, Vehicular AN/VRC-89D |
| A2076 | 10 | Radio Set, Vehicular AN/VRC-90D |
| A2077 | 10 | Radio Set, Vehicular AN/VRC-91D |
| A2078 | 10 | Radio Set, Vehicular AN/VRC-92D |

| | | |
|---|---|---|
| A2079 | 10 | Radio Set, Manpack, AN/PRC-119F |
| A2164 | 10 | Radio Set, Vehicular, AN/VRC-83(V)2 |
| A2167 | 50 | Radio Set, Vehicular AN/VRC-88 |
| A2168 | 50 | Radio Set, Vehicular AN/VRC-89 |
| A2169 | 10 | Radio Set, Vehicular AN/VRC-90 |
| A2170 | 10 | Radio Set, Vehicular AN/VRC-91 |
| A2171 | 10 | Radio Set, Vehicular AN/VRC-92 |
| A2179 | 10 | Radio Terminal Digital, Troposcatter, AN/TRC-170 |
| A2296 | 18 | Relay Assembly, RE1162/U |
| A2306 | 18 | Sensor System, Monitor, Mobile, AN/MSC-77 |
| A2390 | 13 | Sector Anti-Air Warfare FAC, AN/TYQ-87 |
| A2505 | 11 | Switchboard, Telephone, SB-3614(V)/TT |
| A2525 | 13 | Tactical Air Operations Module, (TAOM), AN/TYQ-23 |
| A2535 | 19 | Tactical (Gateway ) Data Network AN/TSQ-222 |
| A2537 | 19 | Tactical Electronics Reconnaissance Processing and Evaluation System, AN/TSQ-90E |
| A2542 | 13 | Advance Field Artillery, Tactical Data System (Mobile) AN/GYK47(V)6 |
| A2545 | 13 | Advance Field Artillery, Tactical Data System (Mobile) AN/GYK47(V)7 |
| A2551 | 19 | Tactical Command System, AN/USC-55A |
| A2629 | 19 | Tactical Control and Analysis Center (TAC-PIP) AN/MYQ-8 |
| A2634 | 19 | Tactical Control Analysis Center, Remote, AN/UYQ-83 |
| A3235 | 18 | Communications Central, AN/TSQ190(V)2 |
| A3255 | 18 | Sensor, Ground Unattended, AN/GSQ-257 |
| A3270 | 13 | Communications Interface System, AN/MRQ-12 |
| A8018 | 97 | Interrogator Computer, TSEC/KIR-1C |
| A8019 | 97 | Transponder Computer, TSEC/Kit-1C |
| A8032 | 97 | Speech Security Equipment, TSEC/KY-58 |
| A8038 | 97 | Electronic Key Generator, TSEC/KG-40A/P |
| A8100 | 10 | Control Group, Radio, OK648/U |
| B0001 | 21 | Air-Conditioner 60Hz, 9,000 Btu |
| B0002 | 21 | Air-Conditioner 60Hz, 18,000 Btu, F18H-38A |
| B0007 | 21 | Air-Conditioner MCS Vertical 60K, Btu, FOOT-2HS |
| B0011 | 21 | Air-Conditioner A/E 32C-39, 18K Btu |
| B0012 | 21 | Air Conditioner, F18T-MPI, 60/400Hz, 18 Btu |
| B0114 | 29 | Boat, Bridge Erection, USCSBMK2 |
| B0120 | 29 | Bridges, Erection Set, (MGB) N3250 MGB |
| B0152 | 29 | Bridge, Medium Girder (MGB), Dry Gap |
| B0155 | 29 | Bridge, Floating Ribbon, 70-Ton |
| B0391 | 26 | Container Handler, Rough Terrain, 50,000 lb, 988B |
| B0443 | 26 | Crane, High Speed, High Mobility, HSHMC |
| B0446 | 26 | Crane, Rough Terrain, Hydraulic, Light |
| B0589 | 23 | Excavator Combat, M9 ACE |
| B0675 | 29 | Fuel Dispensing System, Tactical, Airfield, M1966 |
| B0685 | 29 | Fuel System Amphibious Assault, M69HC |
| B0730 | 20 | Generator Set, 3 kW, 60 Hz, Skid Mounted, MEP-061B |
| B0891 | 20 | Generator Set, 10 kW, 60 Hz, Skid Mounted, MEP-003A/803A |
| B0921 | 20 | Generator Set, Tact Quiet, 10 kW, 400 Hz, MEP-813A/805A |
| B0953 | 20 | Generator Set, 30 kW, 60 Hz, Skid Mounted, MEP-005A/805A |
| B0971 | 20 | Generator Set, 30 kW, 400 Hz, Skid Mounted, MEP-114A/815A |
| B1016 | 20 | Generator Set, Tact Quiet, 60 kW, 400 Hz, MEP-115A/816A |

| | | |
|---|---|---|
| B1021 | 20 | Generator Set, 60 kW, 60 Hz, Skid Mounted, MEP-006A/806A |
| B1045 | 20 | Generator Set, 100 kW, 60 Hz, Skid Mounted, MEP-007A/007B |
| B1046 | 20 | Generator Set, 100 kW, 60 Hz, Skid Mounted, MEP-007C |
| B1082 | 23 | Grader, Road, Motorized, 130-G |
| B1135 | 29 | Helicopter Expedient, Refueling System (HERS) |
| B1291 | 99 | Light Weight Decontamination System, M1731 |
| B1298 | 29 | Line Charge Launch Kit, Trl Mtd, 01365 |
| B1315 | 29 | Mine Clearing Launcher, MK-154, MOD 0 MK-154 |
| B1580 | 29 | Fuel Pump Module (SIXCON) |
| B1780 | 46 | Riverine Assault Craft (RAC) System |
| B1922 | 23 | Scraper-Tractor, Wheeled, 621B |
| B2085 | 29 | Storage, Tank, Module, Fuel (SIXCON) |
| B2127 | 29 | Sweeper, Runway, Vacuum, 600 |
| B2460 | 23 | Tractor, Full-Tracked, W/Angle Blade, T-5 |
| B2462 | 23 | Tractor, Medium, Full-Tracked D7G, Caterpillar |
| B2482 | 23 | Tractor, All Wheel Drive w/Attachments FLU-419 |
| B2561 | 26 | Truck, Forklift, Extended Boom |
| B2566 | 26 | Truck, Forklift, Rough Terrain, 4,000 lb |
| B2567 | 23 | Tractor, AT, Articulated Steering, 644E |
| B2604 | 29 | Reverse Osmosis Water Purification Unit (ROWPU) |
| B2685 | 29 | Welding Machine, ARC, Trl-Mtd DCC353P |
| C2282 | 99 | NBC Reconnaissance System (FOX) M93 |
| DO198 | 30 | TRK, Cargo, 7-Ton, w/Winch (MTVR) MK23/MK25 |
| D0209 | 30 | Power Unit, Front, 4x4, 12 1/2 –Ton , MK 48, Mod 0 |
| D0210 | 30 | Truck, Aviation Refueler Capability (ARC) 2000 4900 6x4 |
| D0215 | 35 | Semi- Trailer, 5,000 Gal Refueler 4x4, Bulk Fuel and Fuel Servicing, M970 |
| D0235 | 35 | Semi- Trailer, 40-Ton Low-Bed, 12- Wheel, M870 |
| D0876 | 35 | Trailer, Powered, Container Hauler 4x4, 22 1/2-Ton, MK14 |
| D0877 | 35 | Trailer, Powered, Wrecker/Recovery 4x4, MK15, Mod 0 |
| D0878 | 35 | Trailer, Powered, 5th Wheel 4x4, Semi-Trl, MK16, Mod 0 |
| D0879 | 35 | Trailer, Powered, 20-Ton Dropside Cargo w/Crane 4x4, MK17, Mod 0 |
| D0880 | 35 | Trailer, Tank, Water, 400 Gal, M149A2 |
| D0881 | 35 | Trailer, Ribbon, MK18/A1 |
| D1001 | 30 | Truck, Ambulance, 4 Litter, Armored, 1 1/4-Ton, HMMWV, M997 |
| D1002 | 30 | Truck, Ambulance, 2 Litter, Soft Top, 1 1/4-Ton, HMMWV, M1035 |
| D1059 | 30 | Truck, Cargo, 5-Ton, 6x6, M813A1/M923A1/M925A1 |
| D1061 | 30 | Truck, Cargo, 5-Ton, XLMB, M814/M927/M928 |
| D1062 | 30 | Truck, Cargo, 5-Ton, XLWB M927/M928 |
| D1064 | 30 | Truck, Aircraft Crash/Structure Firefighting, A/S32P-19A |
| D1072 | 30 | Truck, Dump 6x6, 5-Ton, M817/M929/M930 |
| D1125 | 30 | Truck, Utility, TOW Carrier, w/SA 1 1/4-Ton, w/Winch, HMMWV, M1045/M1046 |
| D1134 | 30 | Truck, Tractor, 5-Ton, 6x6, M818/M931 |
| D1158 | 30 | Truck, Utility, Cargo, Trp Carr, 1 1/4-Ton, w/equip, M998 |
| D1159 | 30 | Truck, Utility, ARMT Carrier, 1 1/4-Ton, HMMWV, M1043/M1044 |
| D1160 | 30 | Truck, Fast Attack (Interim) 1.5 Ton Truck 04751E |
| D1180 | 30 | Truck, Utility, Shelter Carrier, HMMWV, 1 ¼ Ton M1037/M1042 |
| D1212 | 30 | Truck, Wrecker, 5-Ton, M816/M936 |
| E0149 | 40 | Bridge, Scissor for AVLB |
| E0150 | 40 | Launcher, Bridge, Armored Vehicle, M60A1 |

| | | |
|---|---|---|
| E0180 | 43 | Circle, Aiming, M2A2 |
| E0207 | 48 | Command Launch Unit, Javelin M98A1 |
| E0277 | 13 | Data Disiplay Group OD144(V) |
| E0330 | 48 | Equipment Set, Night Vision, AN/UAS-12A/C |
| E0665 | 43 | Howitzer, Medium, Towed 155MM, M198 |
| E0726 | 49 | Interrogator Set, Programmer, AN/GSX-1 (STINGER) |
| E0727 | 49 | Interrogator Set, IFF, AN/PPX-3B, (STINGER) |
| E0796 | 41 | Assault Amphibious Vehicle, Command/Communications, AAVC7A1 |
| E0846 | 41 | Assault Amphibious Vehicle, Personnel, AAVP7A1 |
| E0856 | 41 | Assault Amphibious Vehicle, Recovery, AAVR7A1 |
| E0915 | 48 | Launcher, Assault Rocket, 83mm, MK153, Mod 0 |
| E0935 | 48 | Launcher, Tubular F/GM (TOW), M220E4 |
| E0940 | 42 | Light Armored Vehicle, Air Defense, LAV-AD |
| E0942 | 42 | Light Armored Vehicle, Anti-Tank, LAV-AT |
| E0946 | 42 | Light Armored Vehicle, Command/Control, LAV-C2 |
| E0947 | 42 | Light Armored Vehicle, 25mm, LAV-25 |
| E0948 | 42 | Light Armored Vehicle, Logistics, LAV-L |
| E0949 | 42 | Light Armored Vehicle, Mortar, LAV-M |
| E0950 | 42 | Light Armored Vehicle, Maint/Recovery, LAV-R |
| E0980 | 46 | Machinegun, .50 Cal Browning, M2 |
| E0984 | 46 | Machinegun, Cal .50, M48 |
| E0989 | 46 | Machinegun, 7.62mm, M240G |
| E0994 | 46 | Machinegun, 40mm, MK-19, Mod 3 |
| E0998 | 46 | Machinegun, 7.62mm, LM, M240 |
| E1035 | 43 | Meteorological Station Group |
| E1045 | 43 | MULE, AN/PAQ-3 |
| E1065 | 46 | Mortar, 60mm, M224 |
| E1095 | 46 | Mortar, 81mm, M252 |
| E1145 | 43 | Muzzle Velocity System, M94 |
| E1159 | 46 | Night Vision Sight, Crew Served Weapon, AN/TVS-5 |
| E1210 | 43 | PADS, AN/USQ-70 |
| E1377 | 40 | Recovery Vehicle, Medium, Full-Tracked, M88A1 |
| E1378 | 40 | Recovery Vehicle, FT. Heavy, w/Equipment M88A2 |
| E1460 | 46 | Rifle, Sniper, M40A1 |
| E1475 | 46 | Rifle Sniper, Semi-Auto, .50 Cal, Repeater, M82A2A |
| E1836 | 49 | Control Central Guided Missile, Avenger Fire Unit, AN/TWQ-1 |
| E1837 | 49 | Receiver, Infrared AN/PAS-18 |
| E1888 | 40 | Tank, Combat, Full-Tracked, 120mm Gun, M1A1 |
| E1906 | 40 | Direct Support Electrical System Test Set (DSESTS), AN/USM-615 |
| E1911 | 48 | Test Set, Missile Guidance, AN/TSM-152 |
| E1912 | 48 | Field Test Set, TOW, AN/TSM-140B |

# APPENDIX C: FUNCTIONAL AREA DESCRIPTION

| FA Code | Description |
|---|---|
| 10 | Radios |
| 11 | Communications Support Equipment |
| 13 | Air Command/Control Equipment |
| 14 | Air Support Radar/IFF Equipment |
| 16 | Electronic Equipment |
| 18 | Tactical Remote Sensor Equipment |
| 19 | Intelligence/Surveillance Equipment |
| 20 | Generators |
| 21 | Environmental Control Equipment |
| 23 | Earthmoving Equipment |
| 26 | Materials Handling Equipment |
| 29 | Engineer Support |
| 30 | Trucks |
| 35 | Towed Motor Transport Equipment |
| 40 | Tanks |
| 41 | Assault Amphibious Vehicles |
| 42 | Light Armored Vehicles |
| 43 | Artillery |
| 46 | Infantry Weapons |
| 48 | Anti-Armor Weapon Systems and Direct Support Equipment |
| 49 | Missile Systems |
| 50 | High Density/Low Deadline |
| 97 | Communications Security Equipment |
| 99 | Nuclear Biological Chemical Equipment |

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